Estimation of Reliability of Zimbardo Time Perspective Inventory using Bayesian Approach for the Promotion of Quality Education and Life Long Learning in Engineering Discipline

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ABSTRACT

Commonly reported frequentist measures of reliability like Cronbach's alpha and McDonald's omega, along with the less reported Greatest lower bound coefficient suffer from either underestimation or overestimation of reliability coefficients. Moreover, there is inherent uncertainty associated with the obtained estimates. An alternative approach to resolve this issue can be estimation of reliability of psychological instruments using the Bayesian approach, involving the reporting of posterior distribution of the obtained estimate. In this context, the Zimbardo Time Perspective Inventory Short Form by [17], is chosen for estimation of the reliability of its dimensions, partly due to the lack of consensus in reporting of stable estimates of this estimand in multiple contexts. The data was collected from 187 computer science engineering students of Lovely Professional University, Phagwara, Punjab, during their regular classroom session. R Package '*Bayesrel*' was used to find the Bayesian and Frequentist frameworks-based reliability coefficients of the five dimensions of the scale using RStudio Ver. 2022.12.0+353. Except for the dimensions Present Hedonistic and Future time perspective, the reliability of rest the other three dimensions of time perspective were found to fall short of the acceptable benchmark of 0.6 [31]. The graphical posterior predictive check figures showed good fit between eigen values based posterior unidimensional model and data implied covariance matrices. The psychometric implications of the study in the context of Indian engineering students are discussed.

***Keywords:** Engineering Education, Quality Education, Lifelong Learning, Bayesian reliability approach, Zimbardo time perspective Inventory – Short Form, Bayesrel*

I. INTRODUCTION

The sustainable development goal SDG4, stresses on the achievement of lifelong learning, along with inclusive and equitable quality education for all. The focus of the attainment of this goal is especially in the developing countries and in small island nations. These countries can experience faster economic development, provided they strengthen their engineering sector, whose strength is measured through an estimate namely, the engineering index. Econometric models found that there is a very strong and positive relationship between the GDP and investment per capita indicators of economic development and engineering index of nations as per CEBR report, RADA of 2016. In this context of the significance of the attainment of SDG4 in engineering education, through the aspect of lifelong learning for contribution to continuous professional development, the study by [6] which cited the details of the works of [19], becomes quite pertinent. Also, both lifelong learning and continuous professional development, are strongly linked to an individual's present attitudes and hopes about the future [11], [16], [26], [33] and with future time perspective in particular [12], [14].

A major hurdle to overcome to further explore the relationship of engineering education and time perspectives of its graduates, is the poor psychometric performance of one of the popular instruments to measure time perspective, namely, the Zimbardo time perspective inventory [17]. The tool has an unstable five factors structure [2], [22], which lead to the development of shorter form of this scale. [4] validated the shorter form of this scale with 17 items as developed by [17] in the Indian context and managed to retain the original five factor structure of the scale post deletion of one item of future time perspective dimension, due to its poor performance. While the dimension Past Negative has four items, the rest of the four factors, namely, Present Hedonistic, Present Fatalism, Past Positive and Future Time Perspective have three items each in the revised scale of 16 items. Moreover, a factor must have at least three items associated with it for its individual existence [24] and establish the validity of the factor structure.

However, when the items per factor become less and number of factors in a scale are more, the value of Cronbach's alpha, which is the most popular estimate of internal consistency reliability in Frequentist framework [27], becomes low. Also, Cronbach's alpha assumes normality of the data [7] and unidimensionality of the construct of interest through the criterion of tau-equivalence [1]. These conditions are seldom satisfied practically leading to the underestimation of the reliability of the scale between 0.6 to 11 percent depending on the severity of the violation [25],[8]. Also, every reliability estimation inherently contains uncertainty which is generally ignored by reporting the estimate as a point estimator [18].

To address the above-mentioned issue of uncertainty in reliability estimation, the present study applied a newly developed approach by [21] to calculate the reliability coefficients of Zimbardo time perspective scale using Bayesian approach based on the work of [23]. Here under Bayesian inference, the calculation of the uncertainty in the reliability is measured with the help of a posterior distribution which is the relative probability of different parameter values after the data is obtained. The posterior distribution are themselves based on the choice of a prior distribution which is probability of different parameter values before the data is obtained. During the Bayesian approach based reliability estimation, the prior distribution value gets updated to become posterior distribution with the help of a likelihood function based on Bayes theorem. The posterior distribution helps in the reporting of a credible interval which provides a bracket within which the sought parameters reside with high degree of precision.

II. METHODOLOGY

Sample:

187 (159 males and 28 females) second year computer science engineering students of Lovely Professional University, Punjab, India, selected using simple random sampling technique, after receiving formal permission from the authorities of computer science engineering school, were the sample of this study. The data was collected during regular classroom sessions and the students took 15 to 20 minutes to complete the task.

Measure:

The tool used in the study was the Zimbardo Time Perspective Inventory Short Form [17] with 17 items measuring the five dimensions of time perspective, namely, past positive (e.g. "Happy memories of good times spring readily to mind."), past negative (e.g. "I think about the bad things that have happened to me in the past."), present hedonistic (e.g. "I take risks to put excitement in my life."), present fatalism (e.g. "You can't really plan for the future because things change so much.") and future time perspective ("I am able to resist temptations when I know that there is work to be done."). The responses of the subject were recorded using a five point Likert scale where 1=very uncharacteristic to 5=very characteristic. The item 11, "Meeting tomorrow's deadline and doing other necessary work come before tonight's play", did not perform well in the Indian context [4] and hence was not included in the study.

Statistical Analysis

Four different types and most popular single-test reliability coefficients, namely, [1], [15], [9] and Greatest lower bound [32] were used in this study to report the estimates of reliability of the five dimensions of time perspective construct. Each of these estimates have their own share of merits and demerits. While Cronbach's alpha is the most popular estimate of internal consistency reliability, it assumes normality of the data, tau-equivalence (every item equally effective in measuring its latent factor) and unidimensionality of the construct, which are violated in most of the cases in social sciences research. McDonald's omega addresses the issue of tau-equivalence, but is prone to normality of data. If reliability is defined as the ratio between observed score variance and true score variance, as lower bound of reliability, then Guttman's lambda 2 is a better estimator of reliability for heterogeneous items [29]. Finally, when the data is skewed and the number of items per dimension are fewer, a better performing estimate of reliability over alpha, omega and lambda is the Greatest lower bound reliability [3], which expresses the reliability estimate in terms of a confidence interval (GLB,1). However, the greatest lower bound reliability performs well only when the sample size is large enough, preferably over 1000 subjects [30].

The estimation of these reliability coefficients for the five dimensions of Zimbardo time perspective inventory was conducted using the R package *Bayesrel* [21] on RStudio Ver. 2022.12.0+353. The Bayesian analysis of reliability provided alpha, lamda 2, greatest lower bound and omega coefficients under its own and under frequentist frameworks, allowing for comparison of the performance of the various estimates of reliability simultaneously. The analysis also expresses the Bayesian reliability estimates in terms of credible intervals and frequentist reliability estimates confidence intervals [13], instead of the usual reporting of the reliability estimates a point-estimates ignoring the inherent uncertainty much to the peril of the precision of the study results [18]. The basic difference between 95% confidence interval and 95% credible interval of reliability estimation is that, in the former case, the researcher has to be 5 percent doubtful of the true reliability falling in the interval when samples are repeatedly gathered from the same population, whereas in the latter case with posterior distribution, the researcher can be certain that the credible interval contains 95% of the true reliability within it.

After the estimation of the uncertainty in reliability estimation, the R-package *Bayesrel* helps in the display of the graphical posterior predictive check (PPC) of the factors of the scale treated as a unidimensional model. Here, the posterior predictive distributions of the model parameters are used to check for the model fit between the posterior model-implied covariance matrices and the covariance matrix of the obtained data to find out if the parameters sampled under the unidimensional model appears similar to the parameters observed from the collected data [10]. The exercise produces plots similar to scree plots with gray bars (posterior model-implied covariance matrices) and black dots (covariance matrix of the obtained data). When the black dots are enclosed within gray bars, the model fit is implied to be good.

III. RESULTS

The codes to run on RStudio to compute the Bayesian and frequentist frameworks related coefficients of reliability and their posterior predictive check PPC figures are shown below:

Table 1: Bayesian Reliability Analysis of Present Hedonistic Scale

	Point Est	95% CI Lower	95% CI Upper	R Code
Bayes_alpha	0.53946	0.42647	0.64586	1. Install Bayesrel package
Bayes_lambda2	0.57825	0.47798	0.67283	2. Library(Bayesrel) # Activate the package
Bayes_glb	**0.61817**	0.52145	0.71121	3. Import Present_Hedonistic data file into RStudio
Bayes_omega	0.59588	0.49391	0.68885	4. set.seed(1234)
freq_alpha	0.54373	0.42355	0.64271	5. res <- strel(data = Present_Hedonistic) # Use the function strel to compute the reliability coefficents in Bayesian and Frequentist framework and save the result in "res" matrix
freq_lambda2	0.57955	0.45690	0.67254	6.summary(res) # display results
freq_glb	**0.60566**	0.50458	0.71408	
freq_omega	**0.60566**	0.50746	0.70387	7. omegaFit(res, Present_Hedonistic, ppc = TRUE, cutoff = 0.08, ci = 0.95) # display PPC
NOTE: Bayesian point est is the posterior mean; The acceptable level of reliability of a scale is when its Cronbach's alpha is between 0.6 and 0.7 (Ursachi, Horodnic and Zait, 2015)				**Result:** The reliability of the Present hedonistic scale as per bayesian and frequentist greatest lower bound and frequentist omega coefficients are acceptable.

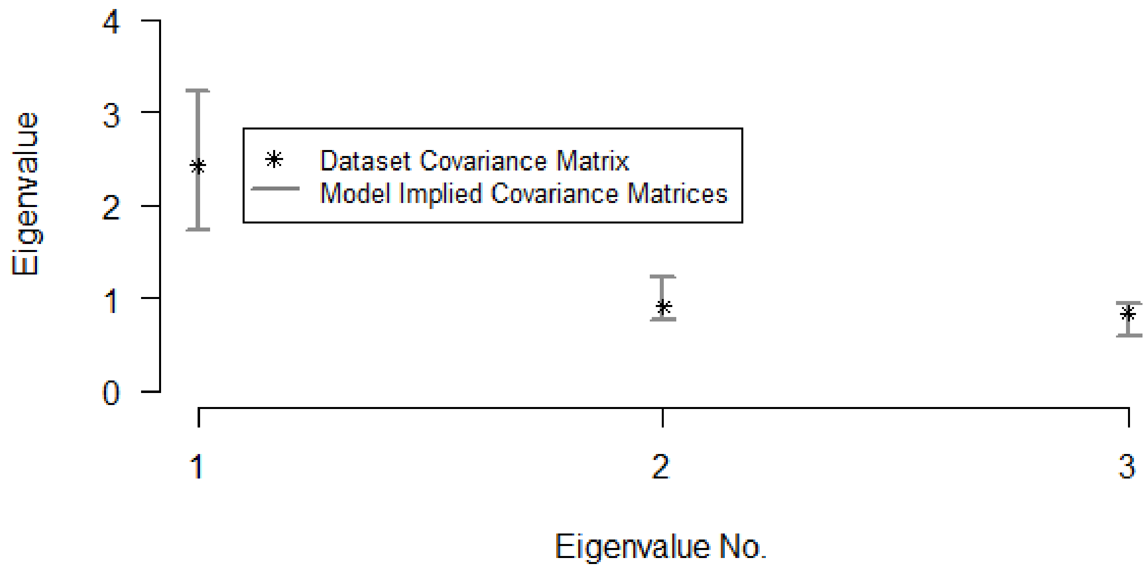

Fig.1 : Graphical Posterior Probability Check – Present Hedonistic Sub-scale Model

Table 2: Bayesian Reliability Analysis of Present Fatalism Scale

	Point Est	95% CI Lower	95% CI Upper	R Code
Bayes_alpha	0.40406	0.25616	0.55319	1. Install Bayesrel package
Bayes_lambda2	0.41073	0.26807	0.55416	2. Library(Bayesrel) # Activate the package
Bayes_glb	0.42714	0.29145	0.56680	3. Import Present_Fatalism data file into RStudio
Bayes_omega	0.39511	0.23205	0.52571	4. set.seed(1234)
freq_alpha	0.40983	0.24597	0.54302	5. res <- strel(data = Present_Fatalism) # Use the function strel to compute the reliability coefficents in Bayesian and Frequentist framework and save the result in "res" matrix
freq_lambda2	0.41044	0.24041	0.55700	6.summary(res) # display results
freq_glb	0.41187	0.27086	0.56409	
freq_omega	0.41187	0.26761	0.55613	7. omegaFit(res, Present_Fatalism, ppc = TRUE, cutoff = 0.08, ci = 0.95) # display PPC
NOTE: Bayesian point est is the posterior mean; The acceptable level of reliability of a scale is when its Cronbach's alpha is between 0.6 and 0.7 (Ursachi, Horodnic and Zait, 2015)				**Result:** The reliability of the Present fatalism scale is not acceptable under Bayesian and Frequentist frameworks.

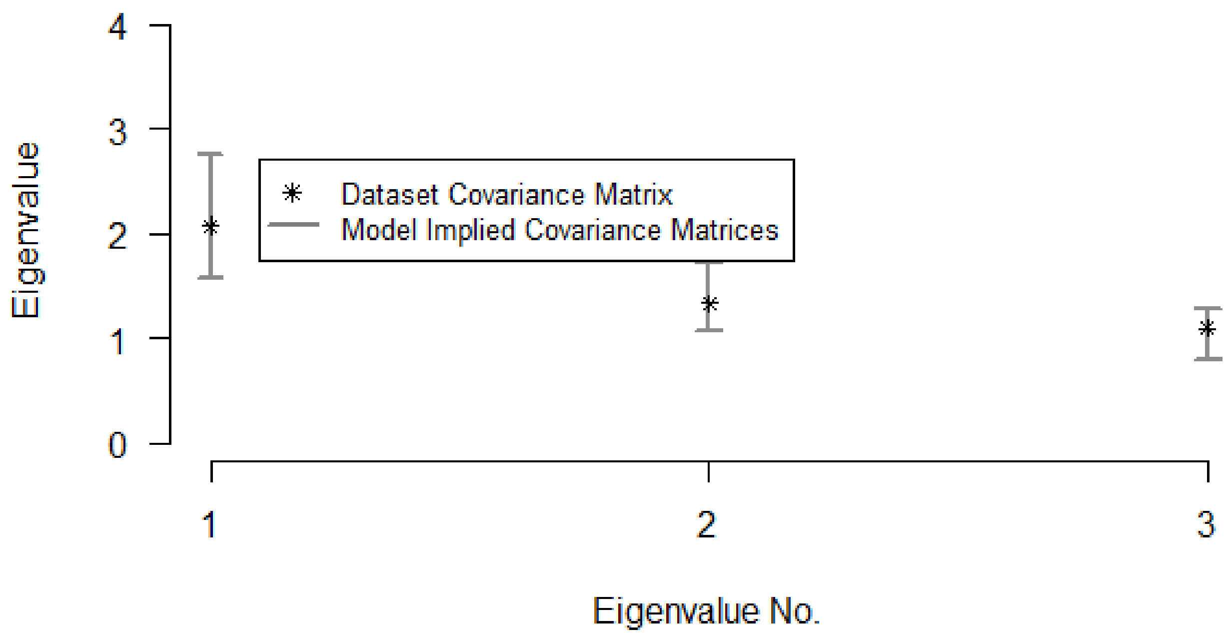

Fig.2 : Graphical Posterior Probability Check – Present Fatalism Sub-scale Model

Table 3: Bayesian Reliability Analysis of Past Positive Scale

	Point Est	**95% CI Lower**	**95% CI Upper**	**R Code**
Bayes_alpha	0.51250	0.39404	0.63845	1. Install Bayesrel package
Bayes_lambda2	0.51891	0.39905	0.63193	2. Library(Bayesrel) # Activate the package
Bayes_glb	0.53313	0.42138	0.64135	3. Import Past_Positive data file into RStudio
Bayes_omega	0.50752	0.39235	0.62112	4. set.seed(1234)
freq_alpha	0.51732	0.38248	0.62674	5. res <- strel(data = Past_Positive) # Use the function strel to compute the reliability coefficents in Bayesian and Frequentist framework and save the result in "res" matrix
freq_lambda2	0.52011	0.36891	0.63660	6.summary(res) # display results
freq_glb	0.52452	0.39414	0.64496	
freq_omega	0.52452	0.40984	0.63921	7. omegaFit(res, Past_Positive, ppc = TRUE, cutoff = 0.08, ci = 0.95) # display PPC
NOTE: Bayesian point est is the posterior mean; The acceptable level of reliability of a scale is when its Cronbach's alpha is between 0.6 and 0.7 (Ursachi, Horodnic and Zait, 2015)				**Result:** The reliability of the Past positive scale is not acceptable under Bayesian and Frequentist frameworks.

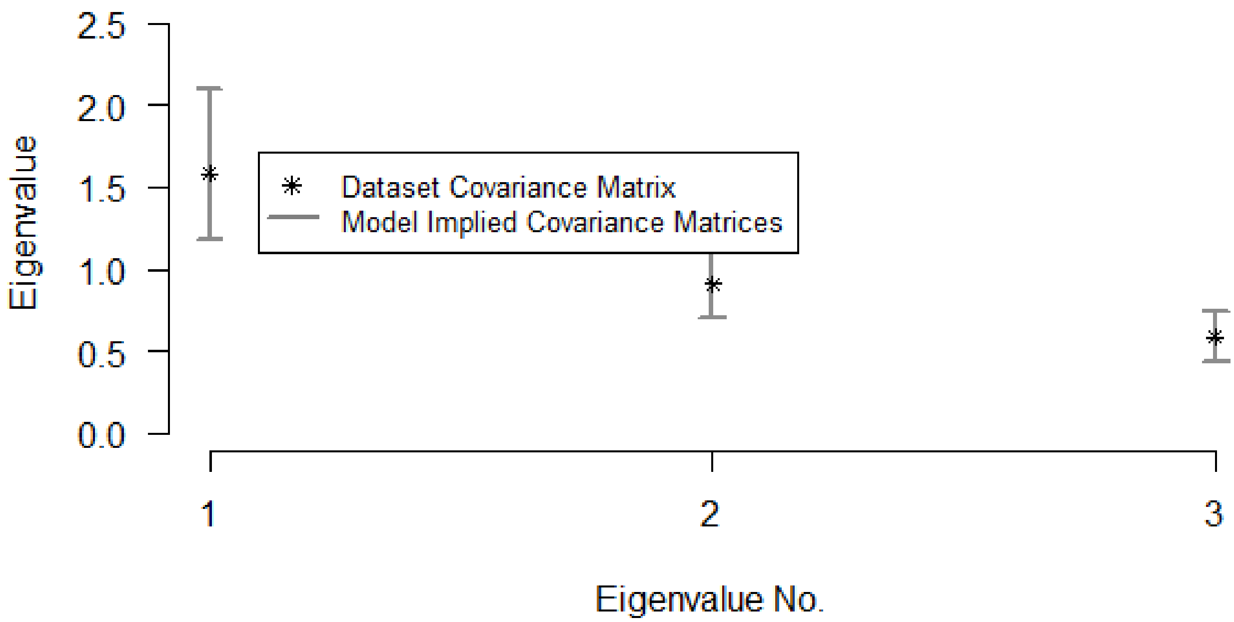

Fig.3 : Graphical Posterior Probability Check – Past Positive Sub-scale Model

Table 4: Bayesian Reliability Analysis of Past Negative Scale

	Point Est	95% CI Lower	95% CI Upper	R Code
Bayes_alpha	0.53023	0.41377	0.63569	1. Install Bayesrel package
Bayes_lambda2	0.53623	0.42620	0.64358	2. Library(Bayesrel) # Activate the package
Bayes_glb	0.57672	0.46619	0.67896	3. Import Past_Negative data file into RStudio
Bayes_omega	0.51907	0.40224	0.62845	4. set.seed(1234)
freq_alpha	0.53568	0.41564	0.63500	5. res <- strel(data = Past_Negative) # Use the function strel to compute the reliability coefficents in Bayesian and Frequentist framework and save the result in “res” matrix
freq_lambda2	0.53668	0.38220	0.65430	6.summary(res) # display results
freq_glb	0.55882	0.43473	0.69801	
freq_omega	0.53692	0.42851	0.64533	7. omegaFit(res, Past_Negative, ppc = TRUE, cutoff = 0.08, ci = 0.95) # display PPC
NOTE: Bayesian point est is the posterior mean; The acceptable level of reliability of a scale is when its Cronbach’s alpha is between 0.6 and 0.7 [31]				**Result:** The reliability of the Past negative scale is not acceptable under Bayesian and Frequentist frameworks.

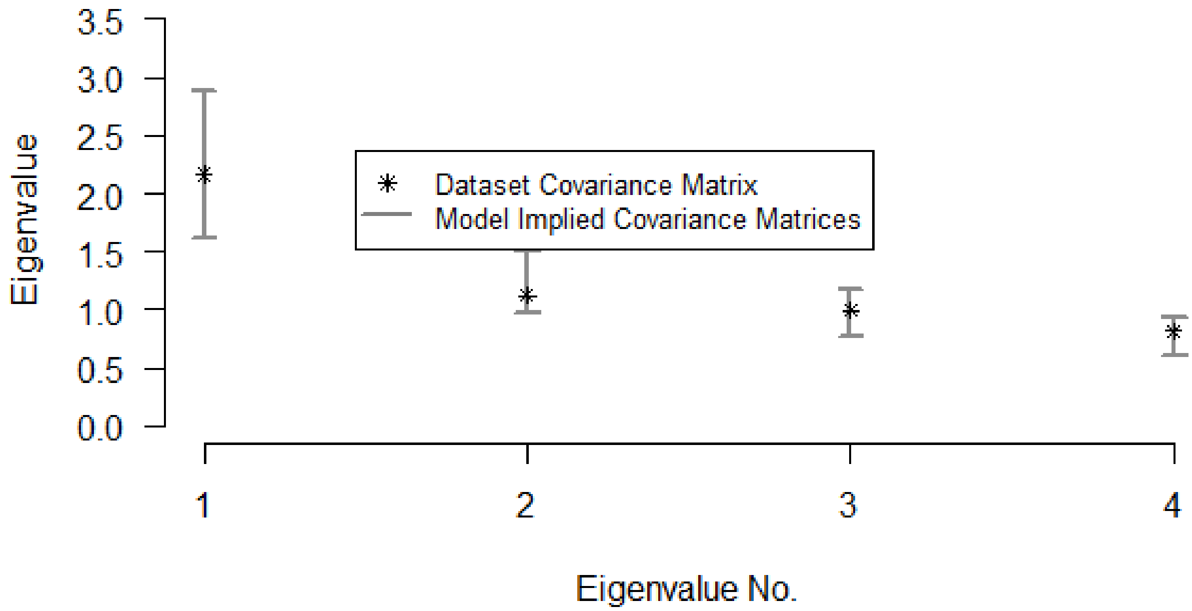

Fig.4 : Graphical Posterior Probability Check – Past Negative Sub-scale Model

Table 5: Bayesian Reliability Analysis of Future Time Perspective Scale

	Point Est	**95% CI Lower**	**95% CI Upper**	**R Code**
Bayes_alpha	0.56102	0.44321	0.65877	1. Install Bayesrel package
Bayes_lambda2	0.58385	0.48749	0.68189	2. Library(Bayesrel) # Activate the package
Bayes_glb	**0.61292**	0.51301	0.70169	3. Import Future_TP data file into RStudio
Bayes_omega	0.59241	0.49381	0.68453	4. set.seed(1234)
freq_alpha	0.56532	0.44747	0.66169	5. res <- strel(data = Future_TP) # Use the function strel to compute the reliability coefficents in Bayesian and Frequentist framework and save the result in "res" matrix
freq_lambda2	0.58525	0.46356	0.67779	6.summary(res) # display results
freq_glb	**0.60307**	0.49903	0.70153	
freq_omega	**0.60307**	0.50621	0.69992	7. omegaFit(res, Future_TP, ppc = TRUE, cutoff = 0.08, ci = 0.95) # display PPC
NOTE: Bayesian point est is the posterior mean; The acceptable level of reliability of a scale is when its Cronbach's alpha is between 0.6 and 0.7 [31]				**Result:** The reliability of the FTP scale as per bayesian and frequentist greatest lower bound and frequentist omega coefficients is acceptable.

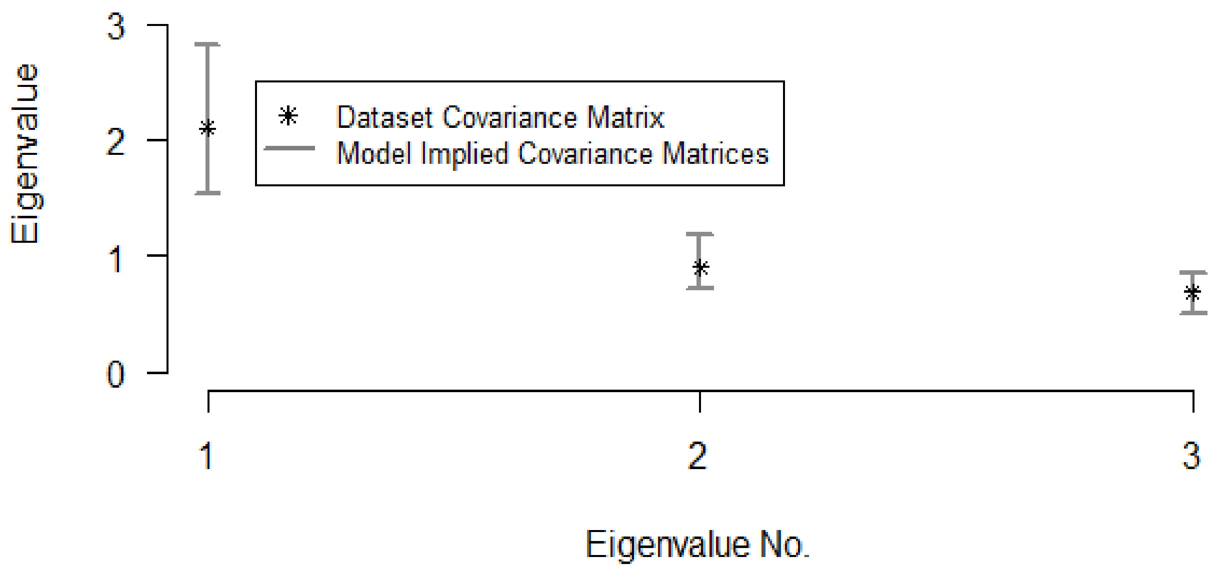

Fig.5 : Graphical Posterior Probability Check – Future Time Perspective Sub-scale Model

Inspection of the PPC figures of all the five sub scales of Zimbardo time perspective inventory reveal the black dots to be well within the grey bars. It implies that the values sampled under unidimensional model of the factors fit well with the obtained data values.

IV. DISCUSSION

The present study tried to bring in a fresh approach of reliability estimation and good practice of conducting reliability analysis on a vital psychological instrument of time perspective, associated with SDG4 goal of inclusive, equitable lifelong learning and engineering education, using Bayesian approach. Without the presence of a robust instrument to measure the time perspective of engineering students, it would be difficult to pursue research on establishing the relationship of lifelong learning and future time perspective on this vital population. The instrument Zimbardo time perspective inventory though adapted in multiple cultures [28] has a volatile factor structure and its obtained reliability coefficients in this present study are also not strong enough, except for present hedonistic and future time perspective time sub scales, even though these coefficients are estimated using two different approaches, namely, Frequentist and Bayesian statistics. However, the single-factor model and collected data covariance matrices were found to fit well through their respective eigen values, since in the PPC figures of all the sub-scales, the black dots were well within the gray bars.

The satisfactory performance of the three items future time perspective sub-scale during its reliability analysis is a welcoming result. It implies that these three items are robust enough to consistently measure this vital sub-scale. The presence of this reliable and already validated [4] tool to measure future time perspective should aid in the conducting of research to future explore the relationship between this vital construct and variables intimately associated to lifelong learning for the engineering population. Such exercises can yield empirical psychometric models which can later pave way to the formulation of appropriate policy initiatives to make engineering education more effective in the country and produce a workforce of professional engineers in the 21st century who are trained lifelong learners.

4.1 Limitations:

The sample size of the present study is small, which influences the prior distribution shape and hence the outcome of the Bayesian reliability analysis exercise. This approach, though robust, is new, along with limited quality work available on engineering education variables in India. Further reliability analysis studies are required to be conducted using easily accessible openwares to establish the reliability of this vital scale on different samples, since reliability as an estimator is sample dependent as well.

V. CONCLUSION

It is hoped that psychometricians in the India would acknowledge the limitations of frequentist point estimators of reliability and adapt the usage of freewares to estimate alternative measures of reliability of psychological instruments based on Bayesian approach. Such exercises would not only lead to more accurate estimation of reliability of the tools but also initiate a culture of good research and its reporting in the country.

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