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Revisiting The Usability of Personalised E-Learning Framework with Social Collaboration Support Using PCA

Amal Al-Abri[a*], Zuhoor Al-Khanjari[b] & Yassine Jamoussi[b]

[a]*College of Computing and Information Sciences, University of Technology and Applied Sciences, Ibri, Sultanate of Oman*

[b]*Department of Computer Science, College of Science, Sultan Qaboos University, Muscat, Sultanate of Oman*

[*]*Corresponding author: amal.b.alabri@utas.edu.om*

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ABSTRACT

Personalised e-learning aims at providing a personalisation effect based on the learner's characteristics such as knowledge level, preferences, and learning style. The support derived from using social collaboration tools like social media reflects the discovery of these characteristics from content generated during collaboration. The collaboration process is guided using different annotations equipped with the collaboration tool. This type of system needs to be evaluated in terms of usability factors including usefulness, ease of use, and System Usability Scale (SUS). These evaluation factors reflect the objectives of the system based on the different functionalities provided. Thus, the correlation between these factors and how they are related to the system objectives is needed to be validated. This validation is performed using Principal Component Analysis (PCA) utilising PerLCol framework as discussed in this paper. PerLCol is a framework that aims at providing personalisation effects by utilising the generated information during social collaboration and interaction. The result reveals the strength items as indicated by the selected components (PC1, PC2, and PC3). These components are related to three evaluated factors which are personalisation, social collaboration, and seamless design which ultimately reflect the objectives of the framework

Keywords: Personalisation; e-learning, social collaboration; Principal Component Analysis; System Usability Scale

INTRODUCTION

With the increased demand for e-learning and the use of social media tools in online education during the pandemic (COVID-19) (Yaseen et al. 2021),(I. R. Al-Kindi et al. 2022), the need for understanding the main factors for successful adoption of it is demanding. Personalization has been identified as one of the main factors for successful e-learning systems (Almaiah et al. 2020; Jogezai et al. 2021). The PerLCol framework is developed to provide personalized e-learning effects with the support of social collaboration tools (Al Abri et al. 2020). Evaluating a like framework is very important to ensure the effectiveness and usability of it. The essential factors to be measured when evaluating a personalized/adaptive e-learning environment are how pedagogically effective and useful the environment is for learning (Brown et al. 2006; Paramythis et al. 2010). Besides, when social collaboration is involved, the annotation functionalities provided should also be evaluated in terms of usefulness and ease of use by the users as the collaboration feature is adopted to support the students during learning (I. Al-Kindi & Al-Khanjari, 2017). Therefore, the focus should be on measuring the usability factor taking into consideration the usefulness and ease of use factors (Alserhan et al. 2023).

Usability is measured taking into account users' perspectives to find areas for improvement for the sake for the targeted users (Lee & Koubek 2010). There are many techniques and tools to perform usability tests like usefulness of the system, ease of use and System Usability Scale. Despite the effectiveness of using multiple techniques for evaluating a personalized system, there is a need to validate the implemented techniques and discover hidden correlations between the evaluated factors.

To interpret the correlations between the different items in the survey or evaluation mechanism, Principal Component Analysis (PCA) can be used. PCA is one of the oldest and most widely used mechanisms to reduce the dimensional aspect of a large dataset in an interpretable and meaningful way (Ian T Jolliffe & Cadima 2016). This technique can generate a coherent and robust set of variables which can be used to evaluate the dataset for any possible changes and direct influences over a period of time (Barreca et al. 2020). It is also supports the discovery and validity of strength factors measured in the evaluation among same hypothesis (Manna et al. 2020).

Aiming at adding more value and meaningful results to the multi factors evaluation mechanisms, PCA is adopted to validate the evaluation of PerLCol as it is going to be discussed in this paper. This technique will focus on discovering the strengths or factors in relation to the objectives of the evaluated system.

The paper is structured as follow: Section 2 provides a background of the main concepts used in the paper. Section 3 discusses the evaluation mechanism followed for usability testing. Section 4 explains the use of Principal Component Analysis to validate the evaluation factors and the results revealed. The paper is concluded in section 5 along with the proposed the future work.

BACKGROUND

PERLCOL FRAMEWORK

Through the use of adaptive learning strategies based on data produced by the actors' (teachers and learners) interactions with the social collaboration tools, the PerLCol framework seeks to provide a personalization effect. Using social media tools and the PerLCol collaborative learning tool, the collaboration and social interaction are improved with more structured and open (not restricted) features (A. Al-Abri, Al-Khanjari, et al. 2019). The personalisation is performed using the three main models of adaptive learning (domain model, learner model, and adaptation model). The PerLCol framework has five main objectives as listed below:

1. To aggregate and map social collaboration content from different social collaboration sources. This objective helps to collect the collaboration content from different sources like social media tools and PerLCol collaborative learning tool and store them in a unified file for further analysis (A. Al-Abri, Jamoussi, et al. 2019).
2. To identify the learning concepts from social collaboration content to build the domain model. This objective guides the construction of the domain model which will direct the generation of personalised learning affect in relation to the discussed concepts during collaboration (Amal Al-Abri et al. 2018).
3. To recognise learners' characteristics from social collaboration content. This objective targets the understanding of the different characteristics of learners which can be identified from the social collaboration. Consequently, it provides a personalised learning effect (A. Al-Abri, Al-Khanjari, et al. 2019).
4. To deliver personalised learning utilising social collaboration content. This objective supports the delivery of personalisation features based on the collected information from collaboration content that are related to the learners' characteristics and learning concept (Amal Al-Abri et al. 2017).
5. To provide structured and opened social interaction to promote collaborative learning. This objective targets the simplification of the analysis of collaboration content by structuring the social interaction process through the development of structured collaboration tool specifically designed for educational purpose(A. Al-Abri, Al-Khanjari, et al. 2019; Al Abri et al. 2020).

The PerLCol framework's learning activity module is intended to assist students as they study. To finish the task, students work together and communicate with one another using various tools for interaction. The PerLCol framework, as illustrated in Figure 1, is made up of interaction spaces where participants can communicate via the LMS (Moodle) module's forum. Collaborative Learning Tool is a social media resource offered by the PerLCol framework that offers learners flexible and structured interaction space. In order to assist students in finishing their assignments, the course instructor must create appropriate learning activities and provide learning materials in the LMS. With the variety of interaction tools at their disposal, students can easily communicate with one another. Additionally, students can share their opinions/ thoughts on the LMS and or PerLCol interaction tool. All details about learning activity, interaction messages, and opinions are stored in a database for future analysis.

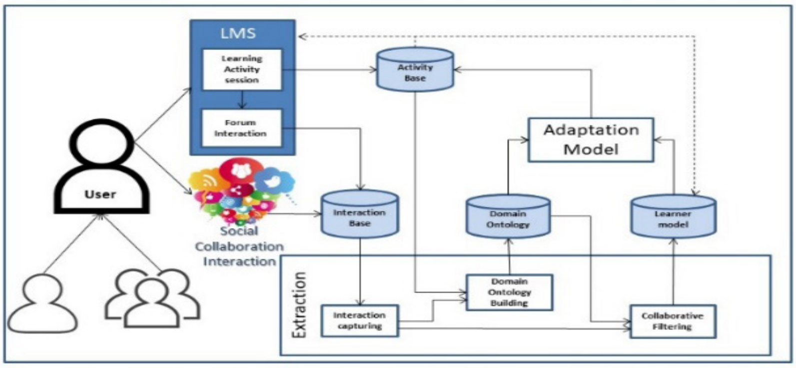

FIGURE 1. PerLCol Framework Architecture

Extraction module of PerLCol framework is responsible to access the database and capture messages from forum and social media tool for pre-processing. This pre-processed data will be analysed to extract the relevant information and make it available for domain and learner models. The domain model represents the learning activity in the form of ontology, whereas the learner model represents information about learners and their personal information such as knowledge, learning style, and social grouping.

The framework's collaborative learning tool component is a social interaction-based tool to structure collaborative learning activities. This tool enriches with features that are like the ones found in social media platforms. Such features will help to facilitate discussion and provides a customised controlled mode to manage the collaboration process. Under the supervision of course instructor, this tool aims at increasing the communication and collaboration features by including other actors such as friends and experts.

As shown in Figure 2, to facilitate collaboration among learners, this tool has four annotation types to facilitate the collaboration between learners (see Figure 2). They are described below:

1. comment, remarks or notes related to a topic or content under discussion. Remarks can include opinions expressed on the shared content.
2. question and answer, a question is raised by any learner and an answer is given by another learner/s.
3. share learning content, share any other external resources related to the topic under discussion.
4. rating, a like or dislike in the form of an opinion expressed by learners on a particular content.

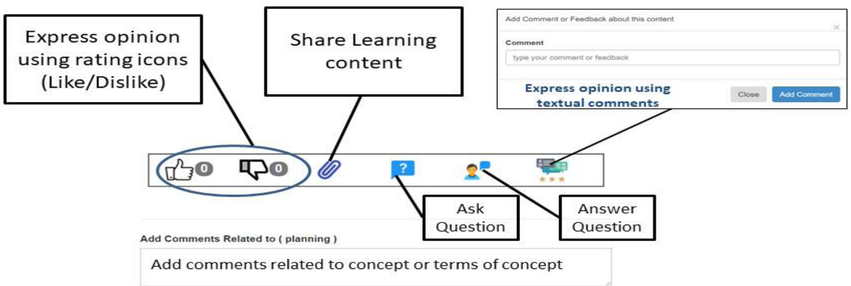

FIGURE 2. Features/ annotation in the PerLCol Collaborative learning tool

USABILITY

To ensure the acceptance and satisfaction of the developed tool, the System Usability Scale testing has been conducted for the tool. SUS is a reliable and widely used test for system or tool usability not only in academia but also in industry (Tullis & Stetson, 2004).

The System Usability Scale (SUS) developed in 1986 by Digital Equipment Corporation. The test has 10 questions with five ranking scale from "strongly disagree" to "strongly agree" as shown in Table 1.

TABLE 1. System Usability Scale items

S. No	Item	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
1	I would like to use this tool frequently	☐	☐	☐	☐	☐
2	I found the tool unnecessarily complex	☐	☐	☐	☐	☐
3	I found the tool easy to use	☐	☐	☐	☐	☐
4	I would need the support of a technical person to be able to use this tool	☐	☐	☐	☐	☐
5	I found the various functions in this tool were well integrated	☐	☐	☐	☐	☐
6	I found there was too much inconsistency in this tool	☐	☐	☐	☐	☐
7	I would imagine that most people would be able to use this tool very quickly	☐	☐	☐	☐	☐
8	I found the tool very cumbersome to use	☐	☐	☐	☐	☐
9	I felt very confident using the tool	☐	☐	☐	☐	☐
10	I needed to learn a lot of things before I would be able to use this tool	☐	☐	☐	☐	☐

The SUS items have been developed according to the three usability criteria defined by the ISO 9241-11 (Borsci et al. 2009). These criteria are:

1. Effectiveness, which is the ability of users to complete tasks using the system, and the quality of the output of those tasks.
2. Efficiency, which is the level of resource consumed in performing tasks.

Satisfaction, which is the users' subjective reactions using the system. The final single score ranges between 0 and 100. The higher the score is, the better the usability. Satisfactory systems or tools are those with a score between 70 and 80. The exceptional systems are those with a score higher than 90 (Bangor et al. 2008).

PRINCIPAL COMPONENT ANALYSIS

Principal Component Analysis (PCA) is a mathematical algorithm that reduces the dimensionality of the data while retaining most of the variation in the data set (I.T. Jolliffe, 2002). PCA is useful step in the validation process as it identifies the underlying component in a survey by extracting the relevant or correlated information (Burton & Mazerolle, 2011). PCA has the ability to identify most related functionalities or components which represent the whole picture or objectives of the system (Bajwa et al. 2009).

PCA is suitable for evaluating systems with different features and functionalities to check the potential hidden links or correlations between these functionalities. PCA makes it possible to visualise and analyse correlations between survey items or variables. This technique has the feature of reducing the number of items in a dataset by combining the items in components aiming at a better understanding of complex reality (Hoang et al. 2018).

EVALUATION OF PERLCOL TOOL

The evaluation of PerLCol tool has been performed using an experimental case study. Around 100 learners participated in the study. The participants in the evaluation are from the department of computer science, Sultan Qaboos University and from the department of information technology, University of Technology and Applied Science-Ibri college of technology. Usability testing of the PerLCol tool considers the testing of usefulness, ease of use, and system usability scale. Usefulness and ease of use are fundamental to be measured to determine the user acceptance and satisfaction of the developed tool (Adams et al. 1992). Therefore, the participants have been asked to complete the designed questionnaire to rate the social features (annotations) available in PerLCol collaborative learning in terms of usefulness and ease of use as illustrated in Table 2. Likert scale questions were stated to get feedback on the provided social features (annotation) by the tool. The participants were asked to select one of the five rating scales for both usefulness and ease of use. The SUS testing is adopted to ensure the acceptance and satisfactory of the developed tool.

TABLE 2. Questionnaire to evaluate the usefulness and ease of use of social annotation features in PerLCol tool.

PerLCol Functionality	Usefulness					Ease of Use				
Sharing/adding comments	1	2	3	4	5	1	2	3	4	5
Reading/browsing shared comments	1	2	3	4	5	1	2	3	4	5
Sharing learning content / (LOs)	1	2	3	4	5	1	2	3	4	5
Reading/browsing shared learning content / (LOs)	1	2	3	4	5	1	2	3	4	5
Rating learning content / (LOs) using like/dislike	1	2	3	4	5	1	2	3	4	5
Rating learning content / (LOs) using textual rating	1	2	3	4	5	1	2	3	4	5
Asking a question	1	2	3	4	5	1	2	3	4	5
Answering a question	1	2	3	4	5	1	2	3	4	5
Reading / browsing shared answers	1	2	3	4	5	1	2	3	4	5
Navigating between main concept and terms of concepts	1	2	3	4	5	1	2	3	4	5

A scale of 1 to 5 is assigned to each response. The description of each these is shown in Table 3.

TABLE 3. Scores assigned to each response in the questionnaire

Score	1	2	3	4	5
Usefulness	Very useless	Useless	Cannot decide/ Uncertain	Useful	Very useful
Ease of Use	Very difficult	Difficult	Average	Easy	Very easy

In addition, personalisation factors measurement is also considered to ensure the satisfaction of the personalisation features provided by PerLCol as shown in Table 4, and the participants asked to response to four statements using a five-ranking scale from "strongly disagree" to "strongly agree".

TABLE 4. Questionnaire to evaluate the personalisation factors provided by PerLCol.

Item	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)
PerLCol Collaborative learning tool enables you to learn the content you need.	☐	☐	☐	☐	☐
PerLCol Collaborative learning tool enables you to choose what you want to learn.	☐	☐	☐	☐	☐
The personalised services provided by PerLCol Collaborative learning tool satisfied your preferences.	☐	☐	☐	☐	☐
The feedback provided by PerLCol Collaborative learning tool is helpful.	☐	☐	☐	☐	☐

The participants in the evaluation were taken from two educational institutions (Sultan Qaboos University and Ibri College of Technology). The questionnaire has been answered by 80 out of 100 participants. The results of the questionnaire analysis can be summarised below.

USEFULNESS OF PERLCOL COLLABORATIVE LEARNING TOOL

According to the ten questions asked to test the usefulness of the PerLCol tool, the response from the participants is illustrated in Figure 3. The responses show that most of the participants feel that all the social annotation features are useful as ranked by more than 27 for each feature.

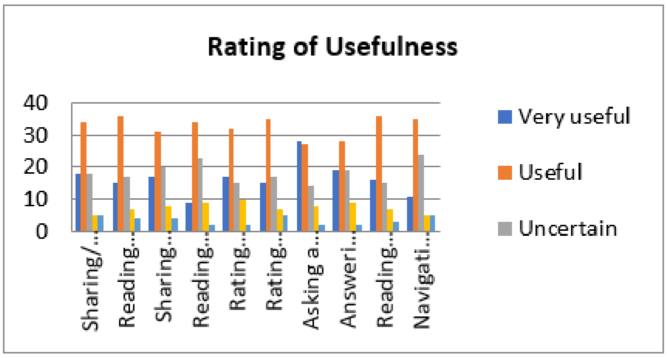

FIGURE 3. Rating of the usefulness of the social annotation features provided by PerLCol tool

To identify the general attitudes of the participants towards the acceptance and satisfaction of the social annotation features provided by the tool, the mean and standard deviation of the results has been calculated. As shown in Figure 4, the mean values of the results which are between 3.5 and 3.9 are more than the neutral response (3). This indicates the positive attitudes (Shi et al. 2013) expressed by the participants on the available features. The values of the standard deviation reported of the overall results are between 0.94 and 1.09 as depicted in Figure 5.

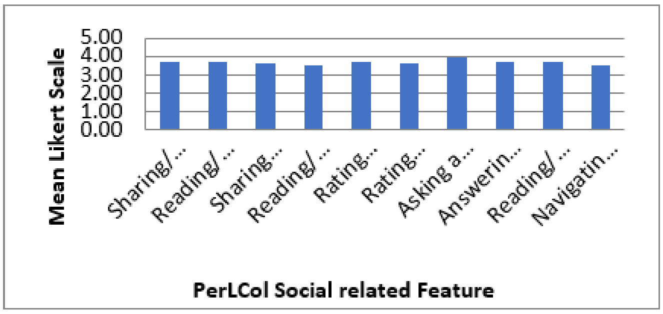

FIGURE 4. Mean Likert Scale for the usefulness of the social annotation features provided by PerLCol tool

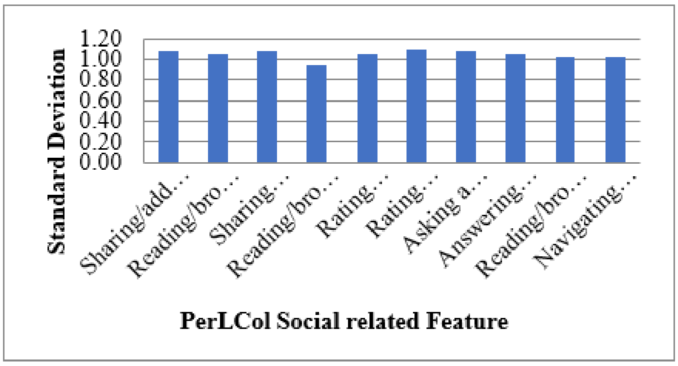

FIGURE 5. Standard deviation for the usefulness of the social annotation features provided by the PerLCol tool

MEASURING EASE OF USE OF THE PERLCOL COLLABORATIVE LEARNING TOOL

The response from the participants on the ten questions asked to test the ease of use of the PerLCol tool is illustrated in Figure 6. The responses show that most of the participants feel that all the social annotation features are easy to use as ranked by more than 25 for each feature.

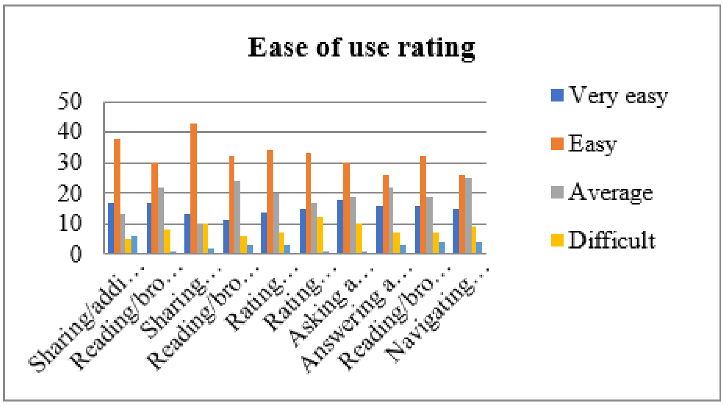

FIGURE 6. Rating of the ease of use of the social annotation features provided by PerLCol tool

The mean and standard deviation of the Likert scale rating for the social annotation features provided by the PerLCol tool are deliberated to identify the opinion of the participants in terms of how easy to use the available features. The overall results show the mean values ranked between 3.49 and 3.71 (see Figure 7) which exceed the value of the neutral response (3). The standard deviation values as illustrated in Figure 8 are between 0.97 and 1.11. These results enable us to conclude that most of the participants found that the social annotation features are relatively easy to use.

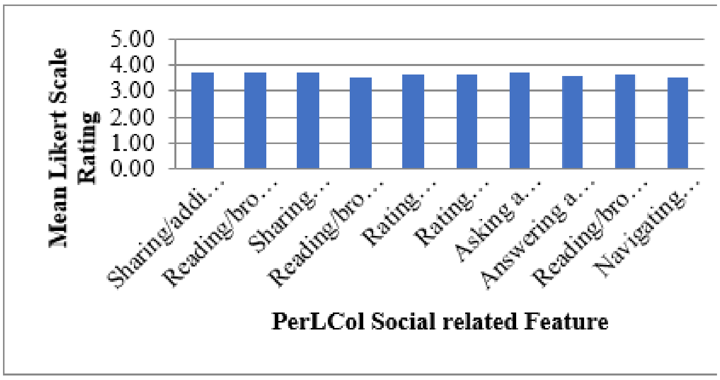

FIGURE 7. Mean Likert Scale Rating for the usefulness of the social annotation features provided by the PerLCol tool

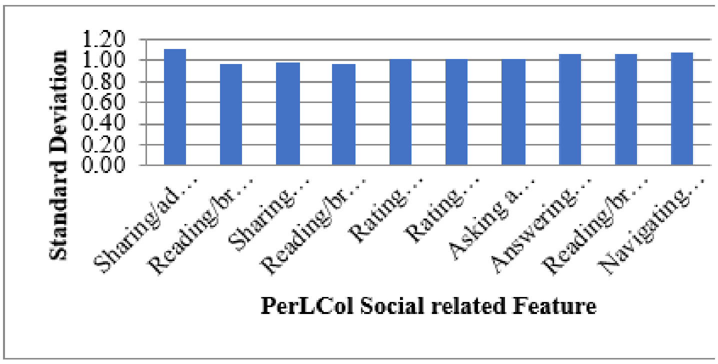

FIGURE 8. Standard deviation for the usefulness of the social annotation features provided by the PerLCol tool

These results illustrate the overall usefulness and ease of use of the tools in terms of the acceptance and satisfaction of the provided social annotation features.

MEASURING USABILITY USING SYSTEM USABILITY SCALE (SUS)

To ensure the acceptance and satisfactory of the developed tool, the System Usability Scale testing has been conducted for the tool. With a score of 70.16, the developed PerLCol tool reached the satisfactory score.

MEASURING PERSONALISATION FEATURES

To measure the satisfaction of the personalisation features provided by the PerLCol tool, participants are asked to respond to four statements using the five-ranking scale from "strongly disagree" to "strongly agree" as discussed before in this section. The generated feedback as shown in Figure 9, indicates a satisfactory result as responses were above 3 (neutral response).

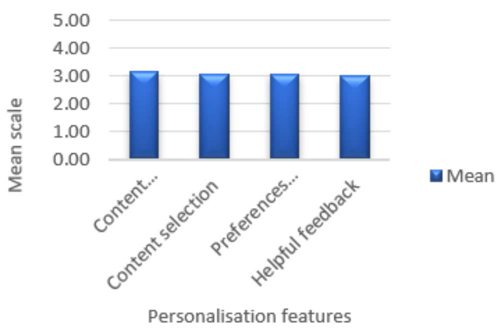

FIGURE 9. The mean scale for personalisation features

PCA FOR VALIDATING PERLCOL FRAMEWORK SURVEY

PCA has been used to validate the evaluation survey of PerLCol through the discovery of the strength in the correlations between the evaluated items. This technique aims to address the concern of underlying correlations between the factors in the usability testing and how they are mapped to the system objectives.

The included dataset for the evaluation, which contains 34 statements, is shown in Table 5. The statements contain items related to usefulness, ease-of use, SUS and personalisation.

PCA has been used to group the dataset in relation to the objectives of the PerLCol framework. Therefore, the initial step is to check if the sample size and the data are adequate and useful to be analysed using PCA. To do so, the Kaiser-Meyer-Olkin measure (KMO) was conducted using formula (6). As KMO of the selected data is 0.784 more than 6.5 (the acceptable value), it is an indication of the suitability and usefulness of the data for PCA analysis. This means a strong correlation matrix between the analysed indicators (statements). With Bartlett's test of sphericity ($\chi 2$ (561) = 2135.5, p <0.001) which tests the overall significance of all the correlations within the correlation matrix, it is statistically significant to perform the PCA analysis on the data. Table 6 shows the KMO and Bartlett's test for the data set.

$$KMO_j = \frac{\sum_{i\neq j} r_{ij}^2}{\sum_{i\neq j} r_{ij}^2 + \sum_{i\neq j} u_{ij}^2}$$

where:
R = [rij] is the correlation matrix and
U = [uij] is the partial covariance matrix.

TABLE 5. Selected statements for the PCA analysis

	Usefulness
S1	Sharing/adding comments
S2	Reading/browsing shared comments
S3	Sharing learning content / (LOs)
S4	Reading/browsing shared learning content / (LOs)
S5	Rating learning content / (LOs) using like/dislike
S6	Rating learning content / (LOs) using textual rating
S7	Asking a question
S8	Answering a question
S9	Reading / browsing shared answers
S10	Navigating between main concept and terms of concepts
	Ease-of-Use
S11	Sharing / adding comments
S12	Reading / browsing shared comments
S13	Sharing learning content / (LOs)
S14	Reading/browsing shared learning content / (LOs)
S15	Rating learning content / (LOs) using like/dislike
S16	Rating learning content / (LOs) using textual rating
S17	Asking a question
S18	Answering a question
S19	Reading / browsing shared answers
S20	Navigating between main concept and terms of concepts
	SUS
S21	I would like to use this tool frequently
S22	I found the tool unnecessarily complex
S23	I found the tool easy to use
S24	I would need the support of a technical person to be able to use this tool
S25	I found the various functions in this tool were well integrated
S26	I found there was too much inconsistency in this tool
S27	I would imagine that most people would be able to use this tool very quickly
S28	I found the tool very cumbersome to use
S29	I felt very confident using the tool
S30	I needed to learn a lot of things before I would be able to use this tool

continue ...

... cont.

	Personalisation
S31	PerLCol Collaborative learning tool enables you to learn the content you need.
S32	PerLCol Collaborative learning tool enables you to choose what you want to learn.
S33	The personalised services provided by PerLCol Collaborative learning tool satisfied your preferences.
S34	The feedback provided by PerLCol Collaborative learning tool is helpful.

TABLE 6. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.784
Bartlett's Test of Sphericity	Approx. Chi-Square	2135.476
	Df	561
	Sig.	.000

The next step is to determine the number of principal components to be considered in the analysis. This step can be identified using the size of the eigenvalue shown in the scree plot in Fig 10. The eigenvalue indicates the amount of variation each principal component captures from the data. The main target is to retain the principal components with the largest eigenvalues. Using the Kaiser criterion, the best selection is the principal components with eigenvalues that are greater than 1. Looking at the eigenvalues of our data set, the first three principal components are determined as they are the best representation of most of the dataset (see Figure 10).

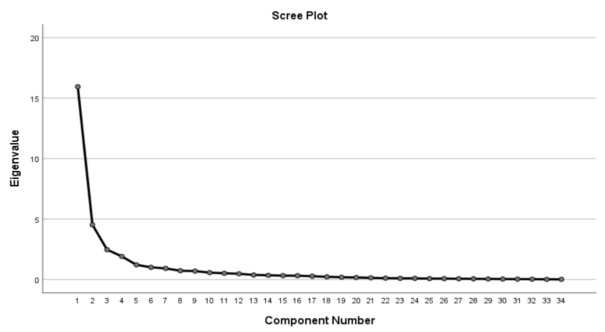

FIGURE 10. Scree plot and parallel analysis of eigenvalue for the survey dataset

MAPPING THE PRINCIPAL COMPONENTS WITH THE RESEARCH OBJECTIVES

The first three components are selected for the PCA analysis as they have the most variation scores explaining about 67.4% of the data. As shown in Table 7, Principal component 1 represents the statements from usefulness and ease-of use of PerLCol, while Principal component 2 represents the odd statements (s21, s23, s25, s27, s29) from SUS and all statements from personalisation testing. The least most variation component 3, represents the even statements from SUS (s22, s24, s26, s28, s30). Therefore, the classification of the principal components based on the represented statements is as follows:

1. Principal component 1 (PC1) is related to the social collaboration annotations provided by PerLCol. Therefore, this component is a representation of the collaboration support feature as in research objectives
2. Principal component 2 (PC2) is related to the personalisation features provided by PerLCol as specified in research objectives 2, 3 and 4.
3. Principal component 3 (PC3) is related to the design aspect of the PerLCol tool. This represents the complexity level of the PerLCol tool in terms of design and how easy to use by users.

An obliging rotation was performed since factors were expected to be correlated. The obtained pattern matrix is displayed in Table 7. Only items with factor loadings of above 0.50 are shown.

TABLE 7. pattern matrix

	Component		
	1	2	3
s4	.925		
s11	.910		
s15	.861		
s19	.847		
s14	.826		
s17	.824		
s13	.810		
s3	.810		
s9	.799		
s1	.799		
s6	.788		
s16	.778		
s2	.771		
s12	.763		
s5	.761		
s7	.760		
s20	.742		
s18	.730		
s10	.706		
s8	.688		
s33		.914	

continue ...

... cont.

s32	.897	
s34	.880	
s31	.870	
s21	.766	
s25	.666	
s29	.638	
s23	.601	
s27	.577	
s22		.836
s24		.800
s28		.758
s26		.757
s30		.626

The mapping between the determined principal components and some of the research objectives are illustrated in Figure 11.

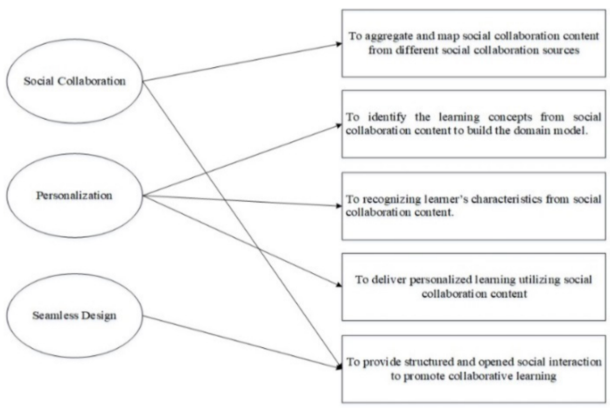

FIGURE 11. Mapping principal components with research objectives

RESULT AND DISCUSSION

The 3D plot for the principal components is illustrated in Figure 12. The 3D plot shows the distribution trend of the different groups (PCs). It reveals clearly that there is a strong correlation in the social collaboration group as all items are toward 1 in the positive side of the social collaboration (PC1). This is an indication of the excellent level of satisfaction in terms of the social collaboration annotations provided by the PerLCol tool. This clearly reveals the high-level utilization of social collaboration tools and annotations features by learners to share their knowledge and doubts. Thus, providing them with a learning platform supported by such functionalities will enhance their satisfaction level.

Looking at the second group PC2 (personalisation), the correlation is good as half the items are towards 1 and the other half are towards 0.5 from the positive side of the PC2 line. This indicates the good satisfactory level in terms of personalisation features provided by PerLCol. Such satisfaction will help to improve the learning knowledge of learners as they have been provided with learning features based on their needs and preferences.

Noting the last group PC3 (Seamless Design), there is quite a good correlation between statements as they are towards the 1 with least most representation of the overall data. This is an indication that the design of the tool is not complex and can be understood without the help of any technical assistance. Providing a design with ease of use features will motivate learners to keep the system as the first choice to be used for learning purpose.

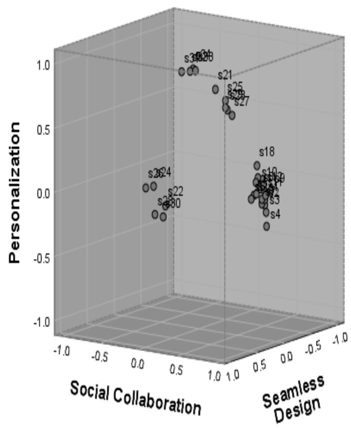

FIGURE 12. 3D Rotation PCA plot

Overall, the evaluation results of PerLCol system indicate that providing learners with a system equipped with different annotations as a means of social collaboration tools that are easy to use, as well as finding contents and options based on their needs and preferences will lead to a high level of satisfaction.

CONCLUSION

Personalised e-learning with the support of social collaboration involves providing personalisation effect like learning content or a learning path using the generated content using social collaboration tools. Thus, the evaluation of such system requires the adoption of different usability measurement like usefulness, ease of use and SUS to check the level of satisfaction in terms of usefulness and ease of use for the social collaboration features provided. In addition, the personalisation features need also to be measured. These evaluation techniques reflect the objectives of the system. This paper focused on the validation of the evaluation mechanism used for PerLCol personalised e-learning system to discover the correlation between the tested factors and how they are mapped to the system objectives. This task has been accomplished using the PCA technique. The result reveals the strength items as indicated by the selected components. These components related to three evaluated factors that are personalisation, social collaboration, and seamless design. These factors eventually reflect the objectives of the system. These results can be considered as a starting point to conduct deeper validation to discover the hidden factors related to the link between personalisation and social collaboration features. This task has been tagged as a future work.

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DECLARATION OF COMPETING INTEREST

None.

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