The Effect of User Experience on Designing Interactive Tool: A Case Study of Learning Images Compression

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ABSTRACT

Technology has significantly emerged in various fields, including healthcare, government, and education. In the education field, students of all ages and backgrounds turn to modern technologies for learning instead of traditional methods, especially under challenging courses such as mathematics. However, students face many problems in understanding mathematical concepts and understanding how to benefit from them in real-life. Therefore, it can be challenging to design scientific materials suitable for learning mathematics and clarifying their applications in life that meet the students' preferences. To solve this issue, we designed and developed an interactive platform based on user experience to learn an advanced concept in the idea of linear algebra called Singular Value Decomposition (SVD) and its applicability in image compression. The proposed platform considered the common design principles to map between the provider in terms of clear mathematical explanation and the receiver in terms of matching good user experience. Twenty participants between the ages of 16 and 30 tested the proposed platform. The results showed that learning using it gives better results than learning traditionally in terms of the number of correct and incorrect actions, effectiveness, efficiency, and safety factors. Consequently, we can say that designing an interactive learning platform to explain an advanced mathematical concept and clarify its applications in real-life is preferable by considering and following the common design principles.

Key words: Electronic learning, Math learning, User experience, User interface

1. INTRODUCTION

The interactive learning object has integrated a group of learning modules that have been found as a new way to improve students' understanding of the complex concept, especially in mathematical concepts. Besides, it makes learning easy and interesting for students to understand their learning subject by themselves. The interactive learning objects have become a widespread practice in many fields, and considerable strategic emphasis has been paid to them [1]. Interactive learning appeared in recent years, which represented a significant challenge in the education sector. The education fields have a lot of the wrong concepts about teaching; one of them as we have one approach of teaching, which is traditional learning. Traditional learning has represented a student as a container whose teachers fill this container with knowledge from them, while the teacher in this approach is represented as an expert or jug who provides students with all necessary knowledge, this approach may be useful in some fields, but if we look at mathematical fields are ineffective way [2].

Design principles and user experience play an important role in education that takes into consideration different aspects of individuals such as differences between people [3], age categories, and so on that give equal opportunity for all and therefore, enhance the quality of learning. These principles work as an assistant guide to build that enable them to apply different principles to the environment to motivate learners such as adapting emotion positive or negative on their environment [4]. Several studies have applied design principles and user experience in different fields of education [3,4,5] to motivate and encourage learners for learning. The most major benefits are facilitating education that should aspire to include all [6].

Linear algebra is a mathematical method used widely in different disciplines such as computer science, engineering. Nowadays, the linear algebra used in the application has grown corresponding to the growth in computing power in the case of hardware and software that required higher capacity [7]. The common linear algebra methods are LU Decomposition, Gaussian Elimination, and the singular value decomposition (SVD). SVD is known as a factorization of the matrix that generalizes the eigen-decomposition of a standard matrix to any m x n matrix via an extension of the polar decomposition, which has many useful applications like signal processing, statistics, image compressing, and face

recognition. Additionally, computational science exploits SVD for information retrieval, seismic reflection tomography, and real-time signal processing [8].

The ongoing focus on SVD by data scientists has brought forward some valuable developments which facilitated the field of image processing. Several studies have been on the applications of SVD. Most of these studies in this field have only focused on applied SVD in different fields, for example, Nousath et al. have applied SVD in the face and object recognition [9] and Yan et al. have used on the video-recommendation system [10]. While Carballo et al. have applied to build a recommendation system in education [11]. Additionally, Prasad et al. have used SVD in contrast enhancement technique to enhance Satellite Images [12]. However, there is still a prevalent gap in understanding the SVD, especially for students who try to self-learn, which has increased the need to build interactive learning objects that explain the SVD method for those who are concerned.

Teachers of mathematics should concentrate on solving a lot of examples in their teaching. Still, the time in the classroom is limited, so the teacher cannot give enough examples for the students to make sure all students understand the materials. The examples in mathematics help students to understand materials in-depth. Moreover, the teachers in the traditional method don't provide students with complex structures, mostly in the classroom focusing on limited and simple structure examples. In the term of interactive learning applications, N. F. Naim et al. developed an application for learning electrical engineering subjects [13], while Nordin, N.F. et al. developed a tool called "Transformer Interactive Learning Tool" to help students of electronic engineering courses to understand transformers [14]. Based on terms of different learning styles, Hamada et al. provided an environment that depended on interactive learning to help students to learn computer science, engineering courses, and related courses, which enabled each student to select the preferred style of learning [1]. According to the SVD method it is difficult to understand through one or two examples due to their steps. The students need a lot of examples to improve their skills to apply SVD to any matrix. Further, the traditional method it's hard to explain the SVD in real application life. Thus, the interactive learning platform comes to improve the understanding of SVD and applied SVD is one of the practical applications; we focused on image compression as a real application of SVD and try to find the answer to the question:

- *Does the application of principles design of user experience affect the learnability of designing interactive learning?*

The remainder of this paper is organised as follows: Section 2 contains the background, section 3 shows the related work, section 4 presents the interactive design, section 5 includes the performance measurement; Section 6 shows the experimental design, section 7 presents the result, section 8 discusses the results, and finally, section 9 concludes our work.

2. BACKGROUND

In this section, the authors highlight the knowledge behind SVD and image compression.

2.1 SVD

SVD is a mathematical linear algebra that is a highly significant numerical signal processing [8]. The theory of SVD implies that any matrix A of m*n decompose the matrix into a product three matrices which are U, S, and V that represents as A=USVT, where S is a diagonal matrix with size m×n, U is an orthogonal matrix of size m×m, and V is an orthogonal matrix of size n×n. The subscript of T refers to the transpose of the matrix [15].

The diagonal matrix S represents all entries of the matrix are zero while the diagonal are numbers, which are called singular values. The orthogonal matrices U and V are the eigenvalues of formula (1) .

$$x_1 = AA^T \text{ and } x_2 = A^TA \qquad (1)$$

To find the eigenvalues of matrix V from determinate $(x_1 - \lambda I) = 0$, and eigenvalues of matrix U from determinate $(x_2 - \lambda I) = 0$

Then you can find the eigenvectors of matrices U and V, which represent $v_i = [x_1 - \lambda I]$ for V and $v_i = [x_2 - \lambda I]$ for U.

The diagonal line of the S matrix is calculated by $b_i =$ and rearrange diagonal in decreasing order.

2.2 Images Compression Using SVD

Image compression techniques play on the decrease in the bits number required in the image to display it without significantly compromising the image quality. Several techniques apply different approaches in image compression; one of them is SVD [16]. The image matrix A is decomposed into three separate matrices U, S, and V, by applying SVD on an image. However, it is not compressed by simply applying SVD to an image. Only a few singular values are retained after applying SVD to compress an image while other singular values are discarded. This is because singular values are set on the diagonal of S in descending order. That first singular value contains the maximum amount of information, and subsequent singular values contain diminishing amounts of information about the image. Therefore, significant image distortion, the lower singular values representing zero or less important information can be discarded [17]. SVD image compression can be illustrated as the following steps [17]:

1. Read image as matrix G with a size m×n
2. Determine the value of k, which denotes the value of eigenvalue, that used compression. The k value must not bigger than m×n/(m+n+1).
3. Apply SVD to matrix G that get 3 matrices L, D, and

R. D matrix with m×n, a diagonal matrix with non-zero singular values of G, L matrix size with m×m, includes G's left singular vectors. R matrix with n×n, which includes the G's right singular vectors. It is represented in the equation (2).

$$G = l_1 o_1 r_1^T + l_2 o_2 r_2^T + \ldots + l_r o_r r_r^T + \ldots + l_n o_n r_n^T \qquad (2)$$

Where r denotes to rank of G, while r >0 , all singular values before r0, all singular values after r =0

4. Regenerate the matrix by taking the first k terms, and remove all singularities after k, as shown in the equation (3).

$$G = l_1 o_1 r_1^T + l_2 o_2 r_2^T + \ldots + l_k o_k r_k^T, \text{ where } k < r \qquad (3)$$

5. The storage space of the compressed image is k×(m+n+1) bytes.

By observing Figure 1, which shows the results of this study, on frames of video, taking different values of k [16]. It is clear that as the value of k is increased, the compressed image approaches the original image. Thus, when k is equal to the range matrix's rank, the reconstructed image is almost the same as the original one [18].

(a) Original frame. (b) k=8 (c) k= 16 (d) k=32 (e) k=128

Figure 1: The Result of the Study. (Seshaiah, M., K N, M. and Michahial, S., 2016)

Aishwarya, K.M. et al. applied the method of SVD to mid-level digital image processing. They aimed to achieve image compression by using less storage space in the memory and simultaneously preserving the useful features of the original image [19]. This study was rare because it brought many factors together in a comprehensive program of theory building and empirical research, which is challenging.

3. RELATED WORK

In this section, we present some existing work that covered the applications of user interface that serve education and image compression using SVD.

Kung et al. proposed an online data modelling tool to help the student learn normalization in the database and draw the diagram [20]. Their tool focuses on giving the student a full understanding of normalization, which leads them to use the 'step by step' button to show what happened in each step in more detail [20]. They concluded that the online platform could not replace traditional teaching, but we have added support learning for students [20]. This study did not consider design principles to enhance the user experience, which may give better results. Compared to this tool, our system uses the system approach of interactive learning with more flexibility in their learning process. While in another major study, Lim et al. applied an experimental study on learning objects on computing mathematics [21]. Their study's key results are that the value of contents must be meaningful and divided into

parts by learning objects and different levels of interaction with giving students control over that [21]. They conclude the learning objects can facilitate learning when taking design under consideration [21]. Not all groups were under the same tutor, and not all tutors have the same IT ability, which may be the limitations of the study. Compared with our system, we applied these chunks to give learners flexibility and avoid confusion on the content layout that enables them to adjust the contents based on their preferences. Moreover, Horváth demonstrated a web-based learning environment that aimed to help students in higher education to learn programming. His environment is applicable to beginner students who have no or less experience in an industrial programming course [22]. Compared to our system, we adapted the concept of the steps as his environment to support beginners and applied different levels of interactivity.

4. THE INTERACTION DESIGN

This section presents the platform that developed, explains the interfaces, and how to design the platform to learn an advanced linear algebra concept like SVD with considering design principles and user experience quality.

The authors developed a platform to explain the SVD concept for a user, then using that concept to compress any type of image. Using the platform allows the user to compress the image by uploading the image and specifying the number of Eigenvalues. The platform displays the steps of the compression with performance measurement tools' values, which are CR, MSE, and PSNR.

In this assignment, the Matlab Graphical User Interface version (2018b) has been used to simplify the interaction between the user and our platform, which can allow the user to enter his inputs without any difficulties. The user interface focuses on the look and feel; it is a connecting point between the user and the application. So, it is a method for communicating with an application or program without seeing complicated code. It is concerned about everything in the application, which are colors, buttons, texts, fonts, layout ... etc. The user interface is playing a critical role in learning applications, which can enhance the learners' understanding that leads to achieving the aim of designing this application or program. A lot of research discussed the effect of designing in education applications. The most important to design applications the user interface must fulfill the user's requirements without adding much complexity that may lead to confusing the learners. Also, the application is expected to be user-friendly; the learners can reach the content and understand how it works quickly. Also, the application must have only the needful knowledge; we must avoid needless information that will hinder the learners and slow down the experienced learners [23].

Kate E.Lee and her team studied the effectiveness of colors on students, and they found that green color makes students

make lower errors and showed more consistent responses [24]. Therefore, the authors found the result of that study is excellent proof that the green color will be a perfect choice for our interactive learning system's background with some white spaces and black texts. For layout, authors made sure to put all the components in one interface to avoid user dispersion, and we divided the interface into two sections, the first for the inputs and the second for the results and outputs so that the use of the application easily and smoothly.

In the following two subsections, the authors explain the platform interfaces in detail in terms of SVD learning and design principles and the advantage of applying those two concepts.

4.1 SVD Learning

When the user runs the platform, a welcome interface appears that describes the SVD concept, as shown in Figure 2. Then, the user will move to the main interface which has a choice to either learn more about SVD or apply SVD on an image for compression. Figure 3 shows the interface "learn more about SVD", that illustrates the compression on rows and columns. Figure 4 represents the interface of image compression. During this experience, the errors will be handled by error messages, as shown in (a) and (b) in Figure 5. To avoid any accidental closure, a message will be displayed when the user closes the platform, as shown in (c) in Figure 5. Table 1 shows how the user can learn SVD using the platform. The alphabet in the first column in the table refers to the letters in Figures 2, 3, 4, and 5, and the second column describes the function of the component which the letter refers to.
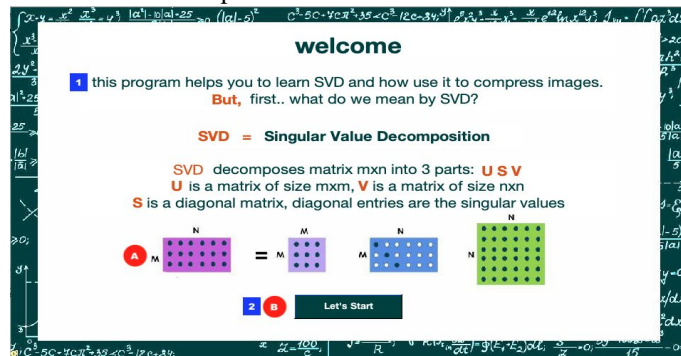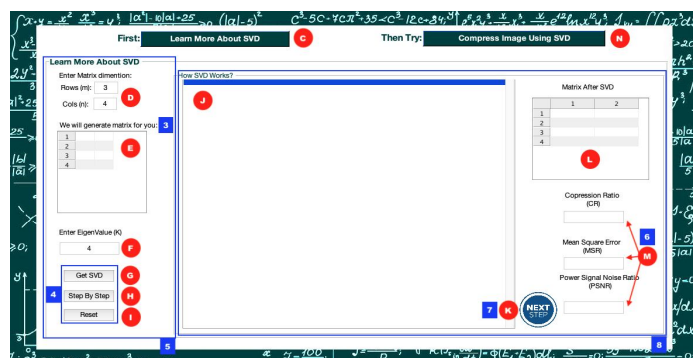

Figure 2: The Platform Welcome Interface

Figure 3: Learn About SVD Interface

Table 1: How the User Can Learn SVD Using the Platform

| Symbol	Function
A	Interface shows the purpose of the application and the basic concept that it will explain.
B	When pressing a (let's start) button, the main interface is shown.
C	The main interface contains two buttons, the first one is C to explain the SVD concept, and the second one is N to compress images. This will give the user the ability to understand the SVD concept before applying it to an image to compress. If the user clicks on C, the input panel will appear, as shown in fig 3.
D	The user enters numbers of rows and columns for the matrix, which allows the user to choose matrix size.
E	The generated matrix appears here. The generated matrix saves the user time and avoids dispersion.
F	The user enters the k value.
G	Button gives the user all results and outputs explanations in detail at once, which suits some learner types.
H	Button gives the user the results and outputs step by step, which suits some learner types. The user needs to press K to show the next step.
I	Button clears the input and output to start again, which gives the user the ability to try again to gain more understanding.
J	Explanation area.
K	Button shows the next steps.
L	Output matrix to compare the input and output metrics.
M	The performance measures' value to notice the effect of K value.
N	If the user clicks on here, the input panel -that differs from the previous panel- will appear, as shown in fig 4.
O	The user enters three K values.
P	The user chooses an image to compress from his computer.
Q	Or choose one of the gallery images.
R	Button gives the results and outputs step by step. The user needs to press T to show the next step.
S	Button gives the results and outputs in detail at once, which suits some learner types.
T	Button shows the next steps.
U	Button clears the input and output to start again.
V	Compression images with different K values appear here next to each other to allow the user to notice the difference in quality and decide which is better.
W	Explanation box.
X	The performance measures table presents the measurement values for each K value, which allows the user to study the results and compare them easily.
Y	The performance measures' charts present the relation between performance measures' values and K values.
Z	Handling error by showing an error message, as shown in (a) and (b) in figure 5.
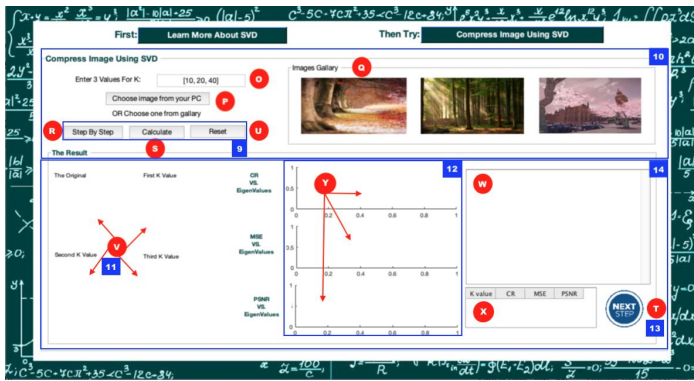
Figure 4: Compress Image Interface

Figure 5: Error Handling in the Interfaces

4.2 Design Principles

Interaction designers used design principles to assist them while designing for the user experience to create a suitable interface that achieves the system goal and fits with the users' needs [25]. There are many principles used in terms of this, but the most common are visibility, feedback, constraints, consistency, and affordance [25]. While authors designed the platform, they focused on those five design principles to achieve the best user experience as possible [25]. Besides that, they considered other important measurement aspects, like effectiveness, efficiency, utility, learnability, and memorability. Table 2 reflects how principles design apply to the proposed design. The first column shows the applied principles design, the numbers in the second column refers to the numbers in Figures 2, 3, 4, and 5, and the last column describes how the principles design applied.

5. PERFORMANCE MEASUREMENTS

In this section, two different types of measurement are explained, one related to image performance measurement, another related to user interface performance measurement.

5.1 Image Performance Measurement

There are three parameters used to measure the performance between original image and compressed, which are Compression Ratio (CR), Mean Square Error (MSE), and Power Signal to Noise Ratio (PSNR)[18].

- **CR:** The ratio of the storage space required to store the original image to that required to store a compressed image.
- **MSE:** The measure of deterioration of image quality as compared to the original image when an image is compressed.
- **PSNR:** The ratio of maximum signal power to the noise power that corrupts it. Noise is the deviation of the compressed image from the original one.

5.2 User Interface Performance Measurement

For user interface performance measurement, the authors used the four of the performance measurements that suggested by Alnanih, R. et al. [26, 27], which are as following:

- **Productivity:** used to measure the Affordance. It is the number of actions performed relative to the time taken by the user to complete the task. The larger the better.
- **Effectiveness:** Number of actions required to complete the task in a specified context of use. The close to 1.0 the better.
- **Efficiency:** used to measure the Visibility. It is the efficiency of the user in completing the task. The larger the better.
- **Safety:** used to measure the Feedback. It is the safety of the user in terms of the number of incorrect actions in the tasks. The closer to 0 the better.

Table 2: How the Principles Design Applying to the Proposed Platform

principles Design	Design Element	Description
Visibility	1 in fig 2	Adding a paragraph to explain the platform purpose.
	2 in fig 2 4 in fig 3 9 in fig 4	Buttons' color is an allusion that buttons are pressable.
	8 in fig 3 14 in fig 4	Inputs grouped into panels as 5 in fig 3 and 10 in fig 4 to facilitate the input process, also the outputs.
	6 in fig 3 11 in fig 4	Outputs that are related to each other are placed together to avoid dispersion.
Affordance	2 in fig 2 4 in fig 3 9 in fig 4	add labels on buttons to describe their functions, then it's easy to remember how to use.
	7 in fig 3 13 in fig 4	The next step button appears only when the user presses step by step buttons, before that, it's invisible.
	1 in fig 2	Important information is written in an attractive color.
Constraints	3 in fig 3	Input that the user does not have to enter is mentioned.
	12 in fig 4	showing the relationships by using charts.
Consistency	fig 2, 3, and 4	The platform abides by the same fonts' colors, buttons sizes, and overall layout, which make everything related.
	fig 2, 3, and 4	Using the common design elements such as a text box and buttons to facilitate the use of the platform, then the user doesn't waste his time to learn how to use it.
Feedback	(a) and (b) in fig 5.	If there is an error, error message display to describe the error and the way to solve it.
	(c) in fig 5.	When the user closes the platform, a confirmation message is displayed to avoid any accidental closure.

6. PERFORMANCE MEASUREMENTS

This section presents the details of the experiment design, including materials, participants, and the environment.

6.1 Image Performance Measurement

An empirical study has been planned and executed through three steps to measure how the interactive design tool is easy to use, effective, and enjoyable.

- **Step 1:** pre-test questionnaire to determine the participants background on image compression and SVD.
- **Step 2:** collecting data attributes during the formal test such as counted incorrect actions, and recorded the time spent on every task; and
- **Step 3:** post- test questionnaire to gather the participants′ feedback and measure the level of their experience toward using the proposed tool.

For the usability testing, the list of tasks is as follow:

- **Task 1:** is learning the SVD concept; this task reflects learnability
- **Task 2:** is a compression image; this task reflects usability

6.2 Participants

The experiment applied to 20 participants. The sample was students from the western region of Saudi Arabia, aged between 18-35 years old, speak English; since English is the platform's language, and familiar with learning mathematics, since the platform explains an advanced concept in math.

6.3 Environment

In line with the precautionary measures taken around the world -Including Saudi Arabia- in the summer of 2020 due to COVID-19, the experiment was conducted remotely. The participants were contacted through a program that allows screen sharing. The screen of the tester was shared with the participant so that all participants use the platform in the same environment without their operating system affecting the experience. While the participants were using the platform, they were monitored to collect some data such as the number of actions, time, etc.

7. RESULTS

This section examines the pre-questionnaire results to split the samples into two groups depending on their background, then analyses the observation results; finally, it discusses the results based on the post-questionnaire to find if we achieve the goal of this study. Analyses pre-questionnaire results present that, as shown in Figure 6, 25% of participants are 16-18 and study at high school, 45% of participants are 19-24 and study for bachelor's degrees, and 35% of participants are 25-39 and have a bachelor's degree at least.

Also, as shown in Figure 6, 50% of participants didn't learn SVD before, while 50% of participants learned SVD in a traditional class. Besides that, 60% of participants didn't hear about image compression, 40% knew images compression, and used different tools to do it.
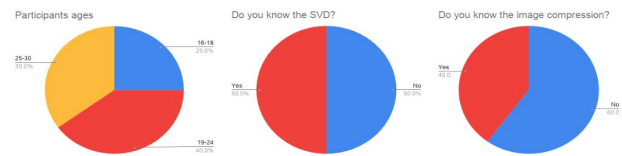

Figure 6: The Pre-questionnaire results

The participants were divided into two groups. The first group for the participants who learned SVD before in a traditional way. The second group for the participants who didn't learn SVD before. Also, the tasks were divided into two tasks, the first one learning SVD and the second one compression image.

The participants were asked to use the platform and complete the two tasks, during that -by observing- the correct action and incorrect actions were counted for each participant in the two tasks individually and calculated the task time.

As shown in Table 3, participants in the first group, who learned SVD before in a traditional way, took an average of 555.8 seconds in task 1 with an average 7.4 correct actions and 1.4 incorrect actions, and an average of 255.54 seconds in task 2 with an average 5.5 correct actions and 0.6 incorrect actions. The participants in the second group, who didn't learn SVD before, took an average of 608.1 seconds in task 1 with an average 6.5 correct actions and 0.6 incorrect actions, and an average of 286.72 seconds in task 2 with an average 4.3 correct actions and 0.1 incorrect actions.

Table 3: The Experiment Result

	Task 1				Task 2			
Participants	Time (s)	correct Action	Incorrect Action	Total # of action	Time (s)	correct Action	Incorrect Action	Total # of action
First Group								
1	454.2	10	2	12	273	3	0	3
2	376.8	11	1	12	194.4	8	0	8
3	378	4	2	6	138	6	1	7
4	318	11	1	12	130	3	0	3
5	800	4	2	6	636	7	1	8
6	366	11	1	12	138	6	2	8
7	465	10	2	12	186	7	0	7
8	420	4	1	5	180	4	1	5
9	480	4	1	5	222	3	0	3
10	1500	5	1	6	458	8	1	9
Mean	**555.8**	**7.4**	**1.4**	**8.8**	**255.54**	**5.5**	**0.6**	**6.1**
Second Group								
11	300	4	0	4	265.2	4	0	4
12	546	11	1	12	246	3	0	3
13	304.2	11	0	11	120	3	0	3
14	316.8	11	1	12	192	3	0	3
15	372	5	0	5	243	7	0	7
16	702	10	1	11	300	8	0	8
17	942	3	1	4	205	2	1	3
18	858	3	1	4	156	3	0	3
19	900	4	0	4	480	7	0	7
20	840	3	1	4	660	3	0	3
Mean	**608.1**	**6.5**	**0.6**	**7.1**	**286.72**	**4.3**	**0.1**	**4.4**

Then, the four user interface performance measurements were calculated for every participant in the two groups, and the average was found out. As shown in Table 4, the participants in the first group in task 1 got on an average of 0.0174 in productivity, 0.5266 in effectiveness, 0.0010 in efficiency, and 0.1816 in safety. In task 2, participants in the first group got on an average 0.0264 in productivity, 0.5915 in effectiveness, 0.0030 in efficiency, and 0.0828 in safety. The participants in the second group in task 1 got on an average of 0.01467 in productivity, 0.7193 in effectiveness, 0.0011 in efficiency, and 0.1007 in safety. In task 2, participants in the second group got on an average 0.0171 in productivity, 0.7982 in effectiveness, 0.0037 in efficiency, and 0.0333 in safety.

After participants finished using the platform, they answered the post questionnaire, and the results were, As shown in Figure 7, that 80% of participants found the understanding SVD was very easy using the interactive platform. 80% of participants, too, found the use of the platform was very easy. Also, 75% of participants were satisfied with using the platform.
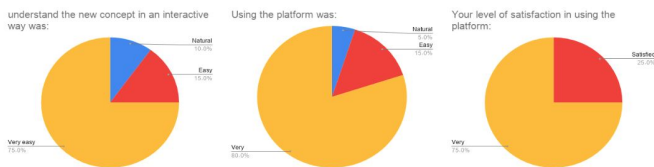

Figure 7: The Post-questionnaire Results

Table 4: User Interface Performance Measurement Results

Participants	Task 1				Task 2			
	Productivity	Effectiveness	Efficiency	Safety	Productivity	Effectiveness	Efficiency	Safety
First Group								
1	0.022	0.333	0.001	0.166	0.0109	1	0.003	0
2	0.029	0.333	0.001	0.083	0.0411	0.375	0.001	0
3	0.010	0.666	0.001	0.333	0.0434	0.428	0.003	0.14
4	0.034	0.333	0.001	0.083	0.0230	1	0.007	0
5	0.005	0.666	0.001	0.333	0.0110	0.375	0.001	0.12
6	0.030	0.333	0.001	0.083	0.0434	0.375	0.002	0.25
7	0.021	0.333	0.000	0.166	0.0376	0.428	0.002	0
8	0.009	0.8	0.001	0.2	0.0222	0.6	0.003	0.2
9	0.008	0.8	0.001	0.2	0.0135	1	0.004	0
10	0.003	0.666	0.000	0.166	0.0174	0.333	0.001	0.11
Mean	**0.017**	**0.526**	**0.001**	**0.181**	**0.0264**	**0.591**	**0.003**	**0.08**
Second Group								
11	0.013	1	0.001	0	0.0150	0.75	0.002	0
12	0.020	0.333	0.000	0.08	0.0121	1	0.004	0
13	0.036	0.363	0.001	0	0.025	1	0.008	0
14	0.034	0.333	0.001	0.083	0.0156	1	0.005	0
15	0.013	0.8	0.002	0	0.0288	0.428	0.001	0
16	0.014	0.363	0.001	0.091	0.0266	0.375	0.001	0
17	0.003	1	0.001	0.25	0.0097	1	0.004	0.33
18	0.003	1	0.001	0.25	0.0192	1	0.006	0
19	0.004	1	0.001	0	0.0145	0.428	0.001	0
20	0.003	1	0.001	0.25	0.0045	1	0.001	0
Mean	**0.014**	**0.719**	**0.001**	**0.100**	**0.0171**	**0.798**	**0.003**	**0.03**

8. DISCUSSION

To find out if there is a statistically significant difference between the two groups, the authors calculated the T-test for every user interface performance measurement for every task. The T-test was a two-tailed analysis for samples with different variance. As shown in Table 5, in task 1, the p-value for productivity was 0.61, for effectiveness was 0.13, for efficiency was 0.66, and for safety was 0.09. In task 2, the p-value for productivity was 0.08, for effectiveness was 0.12, for efficiency was 0.52, and for safety was 0.28. All the p-values were more than 0.05; therefore, it can be said, there is no statistically significant difference between the two groups.

Table 5: T-test for User Interface Performance Measurements

T-test	Productivity	Effectiveness	Efficiency	Safety
Task 1	0.6136739009	0.1354568283	0.664410986	0.09128710036
Task 2	0.08313643983	0.1220937147	0.5266286327	0.2852504178

For that, as shown in Table 6, the authors were comparing the averages of the two groups; and they found that the second group is better than the first group in the correct action numbers, incorrect action numbers, total action numbers, effectiveness, efficiency, and safety. But the first group is better than the second group in time and productivity. And that makes sense since the first group learned SVD before using the platform, unlike the second group.

Table 6: Comparing the Averages of the Two Groups

Group	Group 1	Group 2	Group 1	Group 2
Task	Task 1		Task 2	
Time	555.8	608.1	255.54	286.72
Correct action	7.4	6.5	5.5	4.3
Incorrect action	1.4	0.6	0.6	0.1
Total action	8.8	7.1	6.1	4.4
Productivity	0.01741336416	0.01467454608	0.02640184017	0.01714919839
Effectiveness	0.5266666667	0.7193939394	0.591547619	0.7982142857
Efficiency	0.001090721919	0.001188677455	0.003056671505	0.003714474389
Safety	0.1816666667	0.1007575758	0.0828968254	0.03333333333

Based on the previous results, it can be said that learning the SVD through the interactive platform gives better results than learning it traditionally and also provides better results in understanding the method of applying the SVD in real-life applications such as image compression.

Despite the positive results obtained, there are still some limitations that the platform does not take into consideration,

like supporting different learner patterns. Another limitation is the experiment was conducted with a small sample; maybe a larger sample will give different results.

9. CONCLUSION

With technology extensively present in various fields, including education, people of all ages and backgrounds have turned into using modern technologies for learning. Many factors may hinder the old generation from learning using technology, such as a lack of experience in using it, so scientific materials must be designed to be suitable for this generation without negatively affecting the young generation user.

To solve this issue, an interactive platform was proposed to teach the user an advanced concept in linear algebra called SVD, then explain how to apply it in image compression, which is one of many applications of SVD. To provide a detailed and clear mathematical explanation to the user while taking into consideration providing a good user experience; design principles were supported which led the platform to achieve the study goal.

Twenty users ages 16 to 30 tested the proposed platform, 50% of them had previously traditionally studied SVD. The results showed that learning using the interactive platform yielded better results than the traditional method especially in terms of the total numbers of actions, including correct and incorrect actions, effectiveness, efficiency, and safety.
In conclusion, the authors found that designing an interactive learning platform to explain mathematical methods is possible by applying the design principles. Besides, using the design principles into an interactive learning platform may lead to reduced time spent in the learning. The authors aspire that future research focuses more on adapting the interactive learning platform to support diverse learners' styles to achieve the most significant possible degree of usability.

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