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Gamification Enhances Learning Experience of STEM Courses

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Abstract: ***This work-in-progress is about teaching the students multi-tables in Structured Query Language (SQL) using an interactive application. There are various readily available text books, online courses and educational online forums. Although these resources may provide effective learning, they commonly miss the interactivity component, which can add an element of engagement and possibly fun user experience while learning. This proposed work focuses on the interactive and fun aspects in learning the concepts and principles of SQL queries.***

The project currently includes a high-fidelity prototype implementation. The aim of the prototype is to provide students with information on SQL related concepts through interactive elements that aim to make the learning experience more engaging, fun and appealing. A star based rewarding mechanism was implemented for increasing motivation. Daily-life based metaphors were included in the modules for making it easier for the users to understand the concepts and making the learning experience more enjoyable. For testing and comparison purposes, a traditional paper-based teaching method was also created with the same content. Informal user study sessions were held in a classroom setting with 16 users. Results indicated that the interactive prototype implementation provided more effective learning and a more fun user experience than the traditional method.

Keywords: SQL, Gamification, STEM, Education, Learning

I. INTRODUCTION

Databases are used widely in different real-world applications, which makes it important to know this concept. Data plays an important role in today's world and irrespective of the field one works at; database knowledge is valuable and versatile. The importance of databases constituted the motivation behind this project. There are many database (DB) tools in the market. Some of the most commonly used are as follows: Oracle SQL [1], IBM DB2 [2], MYSQL [3] and PL/SQL [4]. SQL is a widely accepted and useful field to work in nowadays. For many software applications, databases constitute the backbone. With the release of Web2.0 [5], SQL usage has been on the rise. Every time a user visits a webpage, the information most probably comes from some sort of a database, if the webpage isn't static type. SQL can be described as a domain-specific language, which is similar to a programming language, that is mainly used for storing and retrieving information in databases. There are many formats of SQL. Different companies use different formats and structures, but the underlying concepts and syntax remain the same. The main aim for the proposed work-in-progress is to introduce concepts of multi-table queries and facilitate more effective learning through interactivity and incorporated game elements.

The system was designed to be interactive and fun. There are three modules, each module starts with basic theoretical concepts that were kept at the minimum level to avoid overwhelming the users, and then interactive learning mechanism is introduced. After that, users take a quiz about the covered content. Each module has different quizzes. Metaphors were emphasized for easier learning. One of the most important metaphors that I used in the prototype was the 'wardrobe' metaphor, which will be described in more detail in the Metaphor section.

For this works-in-progress project, the Adobe XD [6] software was used to create the high-fidelity prototype and an informal testing was performed.

Target audience is college aged students in their junior year. The target audience was decided based on surveys conducted in the campus of the University of Arizona. Gamification elements were incorporated in the high-fidelity prototype. Users are given stars on completion of a module. At the start, all modules are in a locked state. As the user completes a module, the next module gets unlocked.

Users earn stars on the completion of a module. On the upcoming modules, where learning is expected to be more difficult as the content gets more advanced, more stars are awarded to increase motivation. The number of stars that are awarded are based on the right and wrong answers the users give.

II. BACKGROUND

Databases is not a new computational concept, hence there are several previous works in this area. Here, six previous works that were most related to the proposed works-in-progress project are discussed. Soflano et al. worked on a game-based learning system and measured its effects on teaching SQL [11]. The author developed an educational game with three modes (non-adaptive, customization based adaptive, and dynamically in-game adaptive). An experimental study showed that the game provided better learning outcomes as compared to the textbook-based learning, regardless of the mode. The results of this study encouraged the author to work on this proposed work. Hvorecky et al. studied effects of query language interfaces on user performance [8]. They explored the intersection of query languages, HCI and users' mental and conceptual models. The author performed an educational experiment and tested user performance with different query designs. He found out statistically significant differences in time, accuracy, satisfaction in creating queries and the task difficulty. This study emphasizes the importance of user interface design for favourable user experiences. Along parallel lines, Li and Jagadish emphasized the importance of interaction of HCI with databases for improved usability [9]. They focused on specific fundamental HCI practices that were transferrable to databases, such as information visualization and direct manipulation. The author also mentioned the need for user studies that focus on database usability. As the author aim at adopting suggested HCI practices in the design and evaluate user experience through an informal user study, this previous work aligns with him largely in principle.

Some researchers worked on query optimization, which can be important for the future work steps of this works-in-progress, especially for transferring this prototype implementation into a fully functional content based live application. Li et al. worked on optimization methods for SQL queries and introduced the concept of optimization for queries and the need for it [12]. The author mentioned the underlying reasons behind optimizing queries and furthermore, effects of query optimization on user experience. In their paper, Mithani et al. mentions a novel approach for SQL query optimization, that converts an SQL query into an optimized one, with the main goal of reducing the execution times of the queries [7]. There are several previous studies focusing on gamification. Gaston and Cooper's work mentions the commonly used star-based rewarding system in human computation games and its effects on user experience [10]. The author focused on a protein folding game and compared two versions with a three-star system -one with unlimited moves and the other with a reset mechanism enforcing limited number of moves. It was observed that the three-star system encouraged users to decrease the number of moves, replay the levels they had completed more often and increase the time taken per move. With these motivations, he has incorporated a generic star-based system in our prototype that was integrated with the unique wardrobe metaphor.

III. DESIGN

A high-fidelity application prototype was developed with which users will interact heavily. The application's prototype flow was designed to progress according to the choices the users made. Our main goals with the design can be listed as follows: (1) facilitating effective learning, (2) ease of use, (3) providing an enjoyable user experience. The design was aimed to be user-centered such that the flow was constructed to help the user to navigate through the prototype in an intuitive and effortless way. Each module was designed to be interactive, with the aim of making the experience more engaging through the fun elements incorporated and enhancing the learning experience.As mentioned before, the design was intentionally kept very simple and intuitive. 'Next' and 'Try Again' buttons were used, of which the users already knew the fundamental meaning. Hence, there is no considerable learning curve to the designed interactive prototype. The author's aim with this design is to help users to learn the concepts of databases without investing much time for learning how to use the prototype. A friendly and casual language was used in the prototype with the aim of resonating with users' daily life interactions in a higher degree. The content was aimed to be kept fun and humorous to the best of our capability.

IV. METAPHORS

Some metaphors were utilized to help easier understanding of the SQL concepts. The first metaphor is the closet or cupboard filled with clothes. This metaphor was inspired from daily lives of typical individuals. Every morning, most people opens their closet and finds a pair of clothes to wear for the day. This process of finding the clothes is nothing but a selection of the clothes, from a database perspective. Closet here acts as a database with multiple tables. User finds a t-shirt to wear, this can be similar to a SELECT statement in SQL for getting a t-shirt. If the t-shirt has to be in a specific color, then it becomes similar to using a WHERE clause in SQL for filtering out the irrelevant colors. Selecting a pair of jeans can be similar as well. Selecting both items from different rows of the closet can be paralleled as fetching two different datasets from two different tables, using multi-table SQL queries. In the prototype, the closet was replaced with a bucket, but the concept remains the same.

The second metaphor that was used is selecting a college degree based on user's interests. This metaphor was selected due to its relevant to the target population. The rationale is, since the students have already gone through the college selection experience, they can relate with this metaphor.

V. HIGH FIDELITY PROTOTYPE

The prototype was implemented in the Adobe XD software [6]. The built-in icon library made the implementation process easy. In addition to those, flat icons from an online library called 'Flaticon' were used [13]. Since the target platform for the prototype implementation was Android smartphones, the prototype adhered to Android icons and design guidelines. For implementing the high-fidelity prototype in Adobe XD [6], the following steps were taken: The design board was used for creating the screens. Primarily, the rectangular box functionality was used for creating color layers, which can be seen in the background of the screens. A color scheme of cyan and grey was used. The text box functionality was used for adding text wherever needed. The prototype functionality was used for wireframing the screens and creating an interactive application prototype. During the prototyping process, the author had observed that AdobeXD [6] was very intuitive and easy to use. The objects were made hotspots such that whenever they were tapped, a menu was shown providing some options such as navigating to the proceeding screen and other related settings. The Play functionality in AdobeXD was used extensively for testing the prototype before internally. The screenshots from the high-fidelity prototype implementation are presented in Figures 1 and 2. A flowchart depicting how the prototype system flows and behaves is presented in Figure 3.

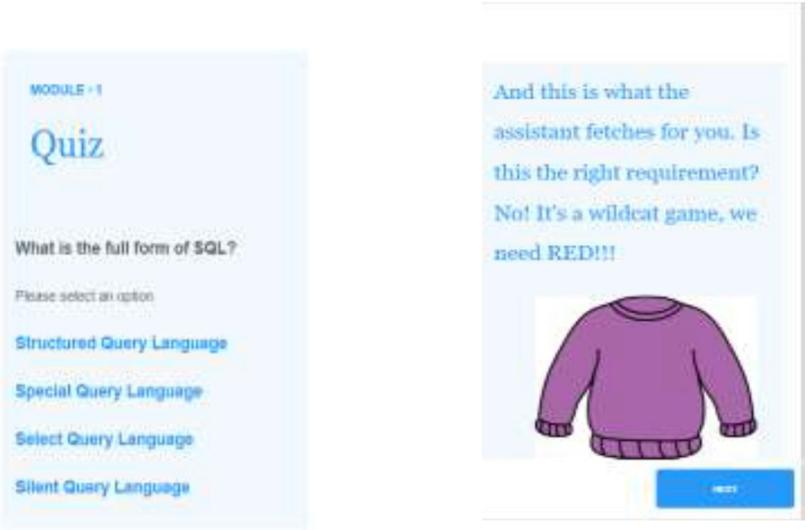

Figure 1 High fidelity prototype screenshots. Left: The quiz screen. Right: The explanation screen.

Figure 2 High Fidelity prototype screenshots Left: The cloth selection metaphor Right: The interactive activity with Gamification

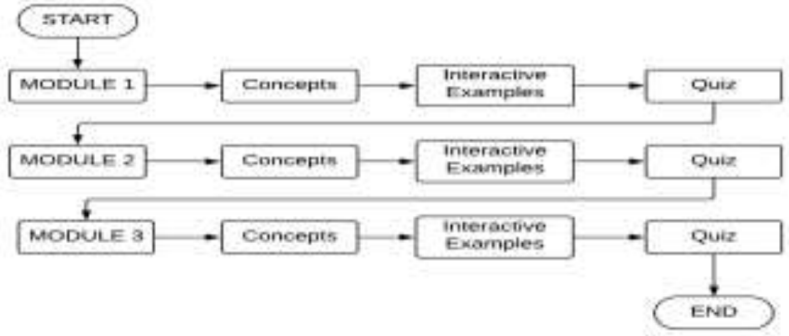

Figure 3: High-level User Journey

Informal Testing

An informal user testing session was held with college students in a classroom setting. For comparison with the interactive prototype, another version was created in the form of a paper-based traditional teaching material. The content and questions in both versions were kept the same for the sake of unbiased data collection. Each participant only tried one of the two versions. The author had two hypotheses: (1) An interactive teaching method will provide more effective learning as compared to the paper-based traditional teaching method. (2) An interactive teaching method will provide a more fun experience as compared to the paper based traditional teaching method. For data collection, surveys were prepared. The surveys included questions mainly about the following: demographics, effectiveness of the teaching method for teaching the concepts, level of interactivity, ease of use and level of frustration. Scale based questions such as effectiveness had an answer scale range of 1 to 5, where 1 being the lowest and 5 being the highest. The survey included some qualitative open-ended questions as well, such as the things users liked the most and the least along with additional comments and suggestions.

Each version was tested by 8 students (a total of 16 users). They were not too familiar with the database concept although some of them had some familiarity. The age range was 20-22 years. Gender distribution was 62.5% male and 37.5% female. The users were assigned the version to be tested randomly. The users who were assigned to test the interactive version went through the entire prototype implementation. They clicked through the screens, learned the concepts that were taught and answered the quiz questions. The average time for completing the interactive version's testing was around 9 minutes per user. The users who were assigned to test the traditional paper-based teaching version also went through the entire material and answered the same quiz questions. The average time for completing the traditional teaching method's testing was around 11 minutes per user.

VI. RESULTS

In this section, the author shares the results that had high importance and yielded interesting implications. Level of frustration with each version was surveyed through a question with three answers: yes, maybe and no. Results are presented in Figure 4 for the two versions. It can be observed that users were in general more frustrated with the traditional teaching method than the interactive prototype.

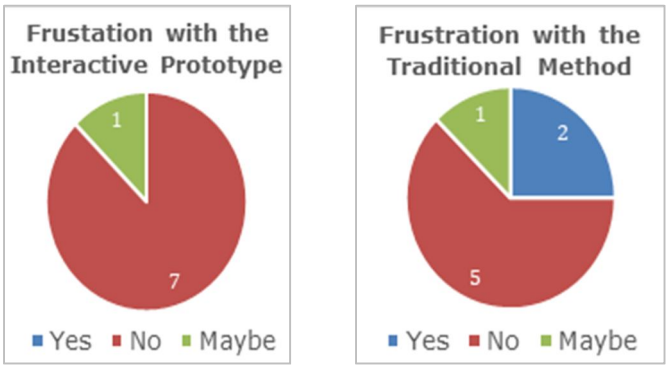

Figure 4 Pie charts for the level of frustration with the two versions. Left: Interactive prototype implementation. Right: Traditional teaching method which was paper-based.

Ease of use metric was also collected through surveys for each version on a scale of 1 to 5, where 5 represents highly easy and 1 represents not easy at all. Results for the average ease of use scores for the two versions are presented in Figure 5. As it can be observed from the bar chart, the interactive prototype was rated as easier to use than the traditional teaching method.

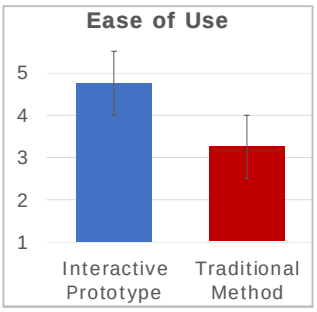

Figure 5 Average ease of use scores for the two versions.

Users were requested to self-report the correct answers they have given, based on the real-time feedback they received in the prototype implementation about the correctness of their answers. Although this is not an accurate form of data collection since users might have forgotten or misjudged the number of correct answers they have given, it was resorted to due to the lack of automated data collection implementation in the high-fidelity prototyping phase. Results for the average self-reported correct answers percentage are presented in Figure 6 for both versions. The interactive prototype resulted in slightly higher correct answers percentage. The users were also asked about the effectiveness of learning they felt with the two versions on a scale of 1 to 5, where 5 represented highly effective and 1 represented not effective at all.

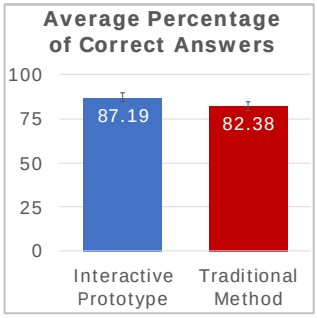

Figure 6 Average percentage of self-reported correct answers.for the two versions.

The results for two versions are presented in Figure 7. As it can be observed from the bar chart, the users rated the effectiveness of learning higher for the interactive prototype implementation. A two-sample t-test was applied to the data with an alpha level of 0.05. The t-test resulted in a p value of 0.019, indicating that there was significant difference between the perceived effectiveness of teaching with the two versions. The result of the t-test can be seen in Figure 8. This supported our first hypothesis.

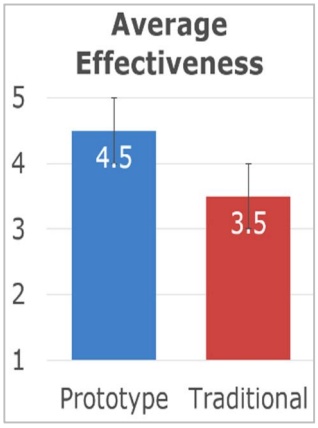

Figure 7 Average effectiveness scores for the two versions.

	Variable 1	*Variable 2*
Mean	4.5	3.5
Variance	0.285714286	0.857142857
Observatio	8	8
Pooled Vari	0.571428571	
Hypothesiz	0	
df	14	
t Stat	2.645751311	
P(T<=t) on	0.009593811	
t Critical on	1.761310136	
P(T<=t) tw	0.019187621	
t Critical tw	2.144786688	

Figure 8 T-test results for the perceived effectiveness of teaching data for the versions.

The users were also asked about their perceived level of fun while using the version they were assigned to test. Results are presented in Figure 9. As it can be observed from the figure, the perceived level of fun was higher for the interactive prototype. A two-sample t-test was applied to the data, which resulted in a p value of 0.00015, indicating that there was significant difference between the perceived level of fun the two versions provided to users. The t-test are presented in Figure 10. The t-test results supported our second hypothesis. As the users were asked about their most positive and negative experience, the most frequently mentioned positive aspects for the prototype implementation was its sleek design, being colorful and interactive. There wasn't any repetitively mentioned negative feedback, however one user mentioned that the text content was long and suggested using bullet points. Some of the notable users' feedback were as follows: "I liked that it was interactive, colorful, and based upon real world situations" "A lot of great information! Friendly user interface! I could keep track of my progress". As the users were asked if they would pay for such an application, their answers indicated that they would be willing to pay a basic amount that is similar to other teaching applications on the market.

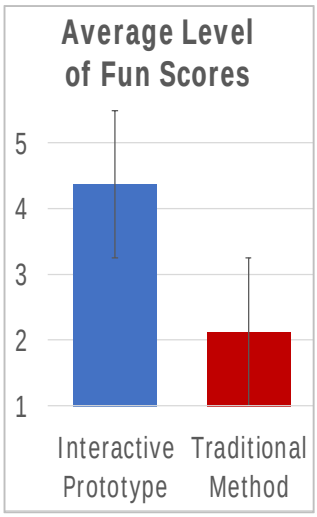

Figure 9 Average perceived level of fun scores.

	Prototype-Fun	*Traditional-Fun*
Mean	4.375	2.125
Variance	0.55357143	0.982142857
Observations	8	8
Pooled Variar	0.76785714	
Hypothesized	0	
df	14	
t Stat	5.13537662	
P(T<=t) one-t	7.5754E-05	
t Critical one-t	1.76131014	
P(T<=t) two-t	0.00015151	
t Critical two-t	2.14478669	

Figure 10 T-test results for the perceived level of fun data for the two versions.

VII. DISCUSSIONS

The t-test results supported our hypotheses of the interactive prototype's being more effective in teaching and more fun to interact with. The author thinks that the underlying reasons behind this are the prototype's implementation being highly interactive while providing control to the user on their pace of learning. The author also thinks that the real-life based metaphors and fun examples helped in keeping users' interest in the prototype implementation. Other possible reasons can be that when students see the number of pages in the traditional teaching material, they can get overwhelmed by the amount of content; also, they are constantly aware of what's next in a textbook whereas there's the element of surprise in the interactive prototype through proceeding screens. As the users didn't know which screen would pop-up next or what will happen if they answered a question incorrectly, the author believes this element of surprise aspect may have contributed to the high scores for the interactive prototype, although formal user studies would be needed to make such a conclusion.

One challenging aspect of the prototyping process was to come up with a design that would cater for the majority of the target audience. As it is known, individuals may have different learning styles and preferences. To overcome this challenge, the author resorted to concepts of Design Thinking and tried to empathize with users while designing the prototype. This emphasized the importance of including users in the design phase and communicating with them continuously for better design outcomes.

VIII. LIMITATIONS

This work-in progress includes a high-fidelity prototype implementation of an interactive teaching application. Due to the nature of the prototyping, there are some imposed limitations such as the number of modules, the level of dynamism in the rewarding mechanism, context-aware adaptability of the teaching material according to user performance, real-time altered variety in the examples. The nature of the questions that were asked during the informal testing sessions is another limitation, as they were all self-declared. Low number of users in the informal testing is another limitation, since it makes the validity of the statistical analyses questionable.

IX. CONCLUSION & FUTURE WORK

For this work-in-progress the author had two aims: designing and developing an interactive prototype incorporating HCI concepts and finding out whether interactivity would promote more effective learning as compared to a traditional teaching method through an informal user study.

Results supported his two hypothesis which expected the interactive prototype to provide more effective learning and a more fun user experience, as compared to the traditional teaching method. The author observed that examples that had connections to real-life experiences such as metaphors helped users to understand the concepts more easily. In conclusion, he believes interactive teaching applications are promising in these aspects.

Future work suggestions for carrying this high-fidelity prototype into a fully functional application are as follows: (1) Dynamically adaptive content to cater for learners' individual needs. (2) Increased modules, content and quiz questions. (3) A dynamic scoring system. (4) Automated navigation to some milestone screens. (5) Live chat support for helping students with their troubles with the application. Also, when the fully functional application is implemented, formal user studies need to be conducted for robust results that would yield concrete implications.

X. ACKNOWEDGEMENT

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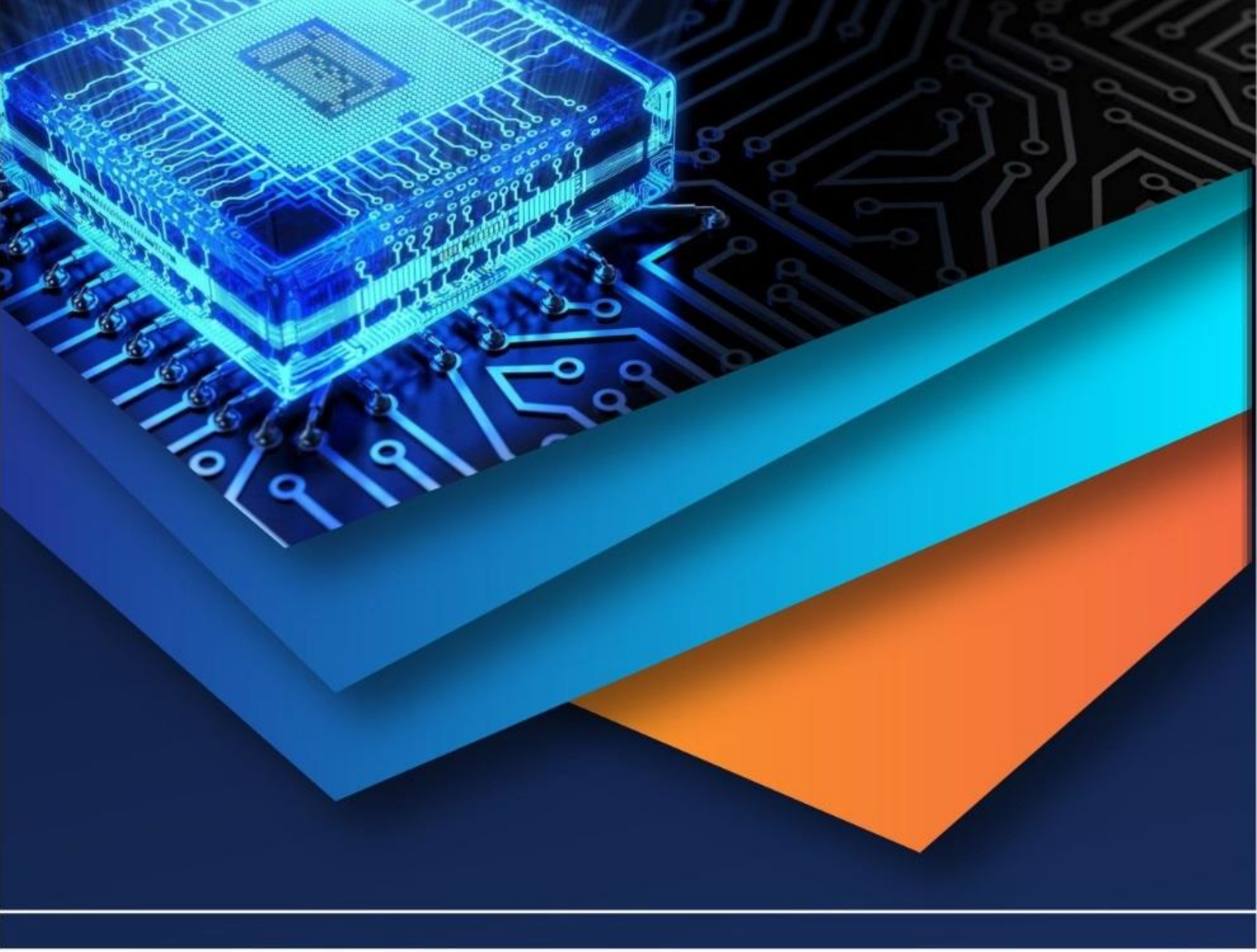
REFERENCES

[1] Oracle SQL. Retrieved from http://www.oracle.com/technetwork/database/database-technologies/sql
[2] IBM DB2. Retrieved from https://www.ibm.com/analytics/us/en/db2/
[3] MYSQL. Retrieved from https://dev.mysql.com/doc/
[4] Oracle PL/SQL. Retrieved from http://www.oracle.com/technetwork/database/features/plsql/index.html
[5] Web 2.0. Retrieved from https://www.oreilly.com/pub/a/web2/archive/what-is-web-20.html
[6] Adobe XD. Retrieved from https://www.adobe.com/products/xd.html
[7] Fazal Mithani, Sahista Machchhar, and Fernaz Jasdanwala. 2016. A novel approach for SQL query optimization. 2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC) (2016). DOI: http://dx.doi.org/10.1109/iccic.2016.7919717
[8] Jozef Hvorecky, Martin Drlik, and Michal Munk. 2010. Enhancing database querying skills by choosing a more appropriate interface. IEEE EDUCON 2010 Conference (2010). DOI:http://dx.doi.org/10.1109/educon.2010.5492434
[9] Fei Li and H.V. Jagadish. 2012. Usability, Databases, and HCI. 2012 IEEE International Conference on Computer Society Technical Committee on Data Engineering – IEEE (2012). Retrieved 9 May, 2018 from https://pdfs.semanticscholar.org/6c95/f8ed38c15d96d0693f2698f24caa2f6d16f9.pdf
[10] Jacqueline Gaston and Seth Cooper. 2017. To Three or not to Three. Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI 17 (2017). DOI: http://dx.doi.org/10.1145/3025453.3025997
[11] Mario Soflano, Thomas M. Connolly, and Thomas Hainey. 2015. An application of adaptive games-based learning based on learning style to teach SQL. Computers & Education86 (2015), Pg: 192–211.DOI: http://dx.doi.org/10.1016/j.compedu.2015.03.015
[12] Dandan Li, Lu Han, and Yi Ding. 2010. SQL Query Optimization Methods of Relational Database System. 2010 Second International Conference on Computer Engineering and Applications (2010). DOI: http://dx.doi.org/10.1109/iccea.2010.113
[13] Icons. Retrieved from: www.flaticon.com



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