NumWorld: A Gamified Approach to Learning Number Systems

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ABSTRACT

The gamified learning application aims to brings users an interactive and engaging learning experience in understanding the four most common number system types. Explore decimals, binary, octal, and hexadecimal with the instructional materials we provided, such as reading materials, video tutorials, and hands-on activities. Also, users may test their knowledge through quizzes, and aim for the leaderboard's top spot

Keywords

Number Systems, Gamified Learning, Decimals, Binary, Octal, Hexadecimal, Quizzes, Leaderboards

1. INTRODUCTION

With the help of emerging technology, learning environments are continually changing and becoming more personalized for users of different ages and learning preferences. Gamified learning applications are a perfect example of this. Gamification and game-based learning are very popular mobile and technology trends that motivate desirable behavior and advance corporate learning outcomes through the usage of gaming features. De-Marcos, Garcia-Lopez, and Garcia-Cabot (2016) define "game-based learning" as the utilization of gamified content as an e-learning strategy to achieve learning objectives. With these gamified learning platforms, learning becomes more fun and engaging as users are able to learn a new skill or subject by playing games, earning points, and climbing leaderboards, which boosts their competitiveness and motivates them to learn more. Levels, points, badges, leader boards, and avatars are the most often used game features in various fields (Barata, Gama, Jorge, & Gonçalves, 2017)[5].

In educational settings, the gamified approach to number systems can be challenging for numerous students who find number systems to be difficult. Drills and rote memorization are common components of traditional approaches, which can be dull and frustrating. Gamification adds excitement and competitiveness by utilizing leaderboards, badges, and points. By integrating real-world events and problem-solving, this not only increases student involvement but also develops their deeper understanding (Adachi and Willoughby, 2013).

For learners who are visual, aural, or kinesthetic, gamified apps and activities can even tailor the learning process. These games' interactive features support learning and improve students' ability to retain information more effectively. Furthermore, students don't have to wait for traditional evaluation methods like quizzes and exams to acquire feedback or results; they can obtain answers right away. Additionally, as students can study and/or learn whenever and wherever they choose with their portable devices, some educational gamification may serve to lessen constraints, such as issues related to time and location. According to Hanus and Fox (2015), these easily navigable resources can simplify complex concepts and aid in memorization. In other words, educational games are thought to make learning more engaging (Calliari, 1991), inspiring (Sun-Lin and Chiou, 2019), achieving knowledge retention (Gros, 2007), improving attention (Prensky, 2003), and even improving social skills and peer communication (Liao et al., 2011)[1].

Gamification offers considerably more entertaining and captivating elements than just addition and subtraction. In fact, gamified learning applications can be powerful tools for introducing learners to more complicated number systems, such as hexadecimal, binary, decimals, and octal. These systems, crucial in computer science and other technical fields, can often seem intimidating and abstract. This is where gamification truly shines, as it breaks down these barriers through the use of interactive exercises, visual aids, and practical applications.

2. REVIEW OF RELATED LITERATURE

Howard and Vaughan (1998) stated that number systems are important for everyone using computers. Understanding the differences between several systems—binary, octal, decimal, and hexadecimal in particular—is part of this. Important digits, positional notation, bases (radix), and units are examples of

fundamental concepts. Furthermore, it is essential that students have confidence doing fundamental mathematical operations such as addition, subtraction, multiplication, and division in several systems and understanding how to convert between them.

Proficiency in binary is crucial for those working in engineering and information technology. This is because of the binary system's heavy reliance on digital electronic circuits, which are constructed from logic gates. Given that binary is so simple to use, almost every modern device we use on a daily basis—from computers to smartphones—uses it at its core. But a lot of beginners are having trouble learning the binary number system for a variety of reasons, including not comprehending the concept, not having enough time to practice, or having trouble understanding the arithmetic operations. People these days are learning through interactive and individualized game play because of the rapid development of digital technologies. Game-based learning (GBL) ensures more effective learning outcomes by providing a more engaging channel for knowledge acquisition in contrast to traditional learning (Ong et. Al., 2021).

Binary Blaster, a multiplayer binary-decimal matching game created by Polycarpou (2011), is one such instance. Players compete to match binary numbers with their corresponding decimal form in this game. Errors result in deductions, while accurate matches yield points. According to research by Polycarpou (2014), Binary Blaster is a simple, entertaining, and useful tool for students to practice converting binary numbers to decimals[3].

In the context of learning number systems, the work of Kuo and Hsu (2020) provides valuable insights. They developed and evaluated a game-based learning platform specifically designed to teach binary, octal, decimal, and hexadecimal systems. Their research found that students who used the platform demonstrated a significantly better understanding of number systems compared to those who relied on traditional instructional methods. The interactive nature of the game, combined with instant feedback and the opportunity to practice repeatedly, was cited as a key factor in the students' improved performance[2].

Gamification in education, a trend that incorporates game-like elements to enhance the learning experience, has proven to be highly effective and is now widely utilized in various educational settings, from primary school classrooms to business training modules. According to Ryan (2022), one of the primary benefits of gamified learning is the higher level of engagement it fosters among students. Unlike traditional methods, gamification involves students through educational games that challenge them and track their progress, allowing them to earn rewards and advance to more difficult levels. Additionally, using stories to guide students through the learning process makes lessons more interesting and helps maintain their focus. Another significant advantage of gamified learning is improved retention, with studies showing that game elements in e-learning modules increase knowledge retention by about 40 percent, ensuring that students remember what they have learned long after their courses are over. Furthermore, gamification connects learning to real-world situations and applications, creating a safe space for students to practice and apply their knowledge, thereby enhancing their

ability to use these skills effectively in real life. Immediate feedback and reinforcement are also key benefits, as students receive instant feedback on their answers, allowing them to correct mistakes promptly and encouraging them to continue learning through rewards for correct answers. Lastly, gamified learning can make education a fun habit, as game elements like rewards and competition stimulate the release of dopamine, a chemical associated with pleasure, making the learning process enjoyable and addictive. Consequently, students may find themselves motivated to learn and improve their skills continuously[4].

3. OBJECTIVE OF THE STUDY

Main objective of developing this gamified learning application is to provide users with a foundational understanding of number systems types such as binary, decimals, octal, and hexadecimal, but also enhance the learning experience of users, specifically students that have subjects or courses that cover these topics.

4. METHODOLOGY

The methodology for developing NumWorld, a gamified learning application for understanding number systems, is rooted in the Software Development Waterfall Model. This approach ensures a structured and systematic process that addresses all necessary phases from initial analysis to deployment and maintenance. By employing this model, the development team can carefully plan, execute, and refine each stage, guaranteeing a comprehensive and user-centered application.
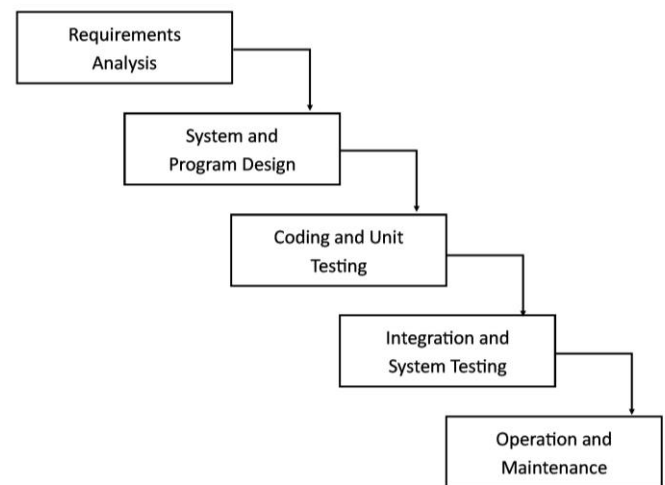

Figure 1. Software Development Waterfall Model

5. Overview of Phases

The development and implementation of NumWorld, a gamified learning application, were structured into distinct phases to ensure a systematic and comprehensive approach. Each phase was meticulously planned and executed, focusing on critical aspects such as initial concept development, design, implementation, testing, and evaluation. This structured approach facilitated the integration of interactive and gamified elements effectively, ensuring the application met its educational objectives.

5.1. Requirements Analysis Phase

In this phase, the proponents carefully identify and document the requirements needed to build the NumWorld application. This includes specifying the types of number systems to be covered (binary, decimals, octal, hexadecimal), the instructional materials to be provided, and the gamification elements to be integrated (quizzes and leaderboards). Detailed system requirements, including necessary functionalities to achieve the expected results, are also outlined.

5.2. System and Program Design Phase

During this phase, user interface prototypes and system architecture are designed based on the defined requirements. The design focuses on seamless navigation and engaging user experiences through interactive elements. Feedback from students and educators is incorporated to refine the design and ensure it meets educational needs and expectations.

5.3. Coding and Unit Testing

In this phase, the actual coding of the NumWorld application takes place. Developers implement the core features, such as user registration, learning materials, quizzes, and gamification elements. Unit testing is conducted simultaneously to ensure that individual components function correctly and meet the specified requirements.

5.4. Integration and System Testing Phase

This phase involves integrating the various components and features of the application into a cohesive system. Comprehensive system testing is conducted to evaluate the overall functionality, performance, and security measures. Usability testing is also performed to assess the user experience and ensure access control mechanisms work as intended.

5.5. Operation and Maintenance

After successful system testing, the NumWorld application is deployed for use. This phase includes ongoing monitoring and maintenance to ensure the application runs smoothly and efficiently. Any issues or bugs identified during this phase are addressed promptly, and updates or enhancements are made as needed to improve the application based on user feedback.

6. Supporting process plans

This section contains supporting processes that span the duration of the software project. This plan includes configuration management, verification, and validation plans.

6.1 Configuration management plan

In the configuration management plan, the actual start and finish dates of the project will be documented as progress occurs. Dates documented will be monitored and should be completed according to the project plan. The project manager will do weekly monitoring.

6.2 Verification and validation plan

The verification and validation plan contains the software project's scope, tools, techniques, and responsibilities for verification and validation of the project.

Several tasks make up for continuing activities that go across the different phases. The general activities will be traceability analysis, evaluation, interface analysis, and testing. The activities mentioned will be the basis of the project that tie the subsequent phases and verification together; with this, it will be more effective.

6.2.1 Traceability analysis

Traceability analysis ensures the fulfillment of learning objectives and educational requirements by tracing them throughout the game's development, from concept to implementation. This allows verification of features set forth in the concept and that required specification carried to design specification, code components, and test cases, enabling easy tracking and verification of requirement coverage.

6.2.2 Evaluation

Evaluation assesses the game's progress and performance against predefined criteria, such as learning outcomes, user engagement metrics, and stakeholder feedback, allowing for timely adjustments and improvements. Regular evaluations allow for early identification of potential issues and prompt corrective actions, ensuring that the game remains on track and aligned with its approach.

6.2.3 Interface analysis

Interface analysis ensures compatibility and proper communication between different game components, such as user interfaces, game mechanics, and educational content, ensuring a seamless and cohesive learning experience. Analysis involves identifying and defining the interfaces, protocols, and data formats required for seamless integration and interoperability, minimizing the risk of compatibility issues, and ensuring smooth system operation.

6.2.4 Testing

In this section, it conducts tests to validate the functionality and educational effectiveness of individual game components, such as mini-games, tutorials, and interactive exercises. It helps identify and resolve defects early in the development lifecycle, ensuring that each component meets its specified requirements.

6.2.5 Component Testing

Compound testing tests multiple game components together, ensuring their correct operation and integration, and validating the overall learning experience. It helps identify issues related to component integration and compatibility, ensuring that the game components work seamlessly together.

6.2.6 Integrating Testing

The integration of different game modules or components, verifying that they work together seamlessly and provide a consistent and engaging learning experience. It verifies that the integrated components communicate and interact correctly, ensuring that the overall system functions as intended.

6.2.7 System Testing

Validates the entire game against educational requirements and stakeholder expectations, ensuring that the game effectively teaches number systems and provides a fun and immersive learning environment. It ensures that the integrated system meets all functional, non-functional, and performance requirements, and that it operates correctly under various scenarios and conditions.

6.2.8 Acceptance Test

Final testing phase Involves testing the system in an operational environment to determine its readiness for deployment and to ensure that it meets the customer's acceptance criteria and expectations. Involves educators, students, and stakeholders to determine the game's readiness for deployment and to ensure it meets their acceptance criteria and expectations.
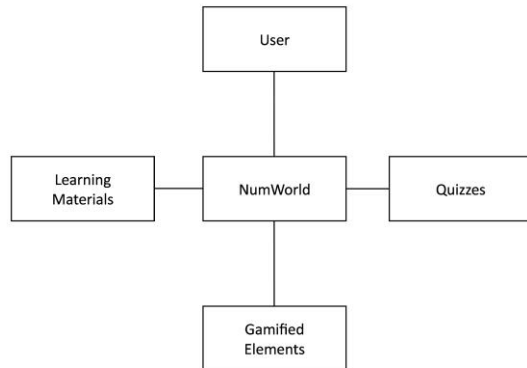
7. Architectural Design

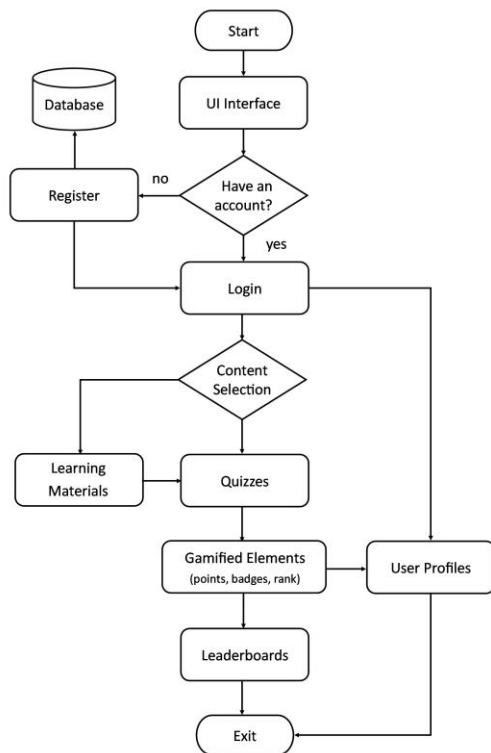**Figure 2. Context Model for Gamified Number Systems Learning App**
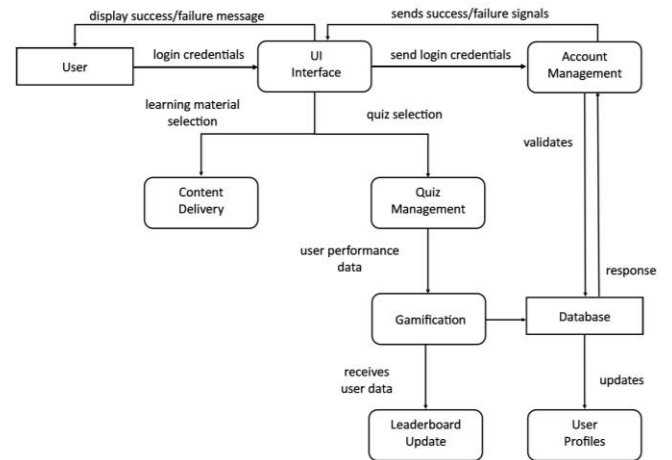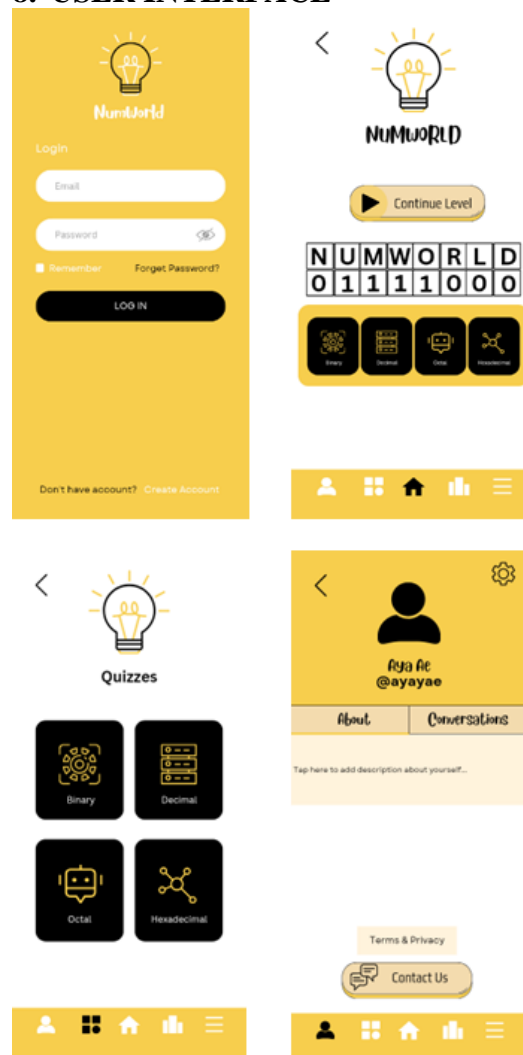

Figure 3. System Flowchart

Figure 4. Data Flow Diagram

8. USER INTERFACE

9. Software Testing

System Features	Description	Actual Results	Pass/Fail/ Not executed/ Suspended
User Account	Users can create account to access the application's functionalities.	As expected	Pass
User Profiles	Showcase the user's identity (username /avatar), progress (stats and badges) and ranking within application.	As expected	Pass
Learning Materials	Educational content like text, videos, and activities that help users understand number systems.	As expected	Pass
Quizzes	Utilize interactive questions to test users knowledge and understanding of number systems.	As expected	Pass
Gamefication Elements	Leaderbards, badges, and points to motivate and engage users in learning.	As expected	Pass
Social Features	Connect with other users and share achivements.	As expected	Pass

Table 1. System features tested

10. RESULTS AND DISCUSSIONS

After the survey was conducted, the data was tabulated. Then, the mean and the standard deviation were computed each item in the questionnaire. The tables found in succeeding page summarizes the results of the survey and its discussions.

Item	Question	MEAN	SD
1	I think I would like to use this software frequently.	4	0.77
2	I found this software unnecessarily complex.	3.5	1.02
3	I thought this software was easy to use.	1.9	0.83
4	I think I would need assistance to be able to use this software.	2	0.77
5	I found the various functions in this software were well integrated.	3.8	1.7
6	I thought there was too much inconsistency in this software.	1.9	0.71
7	I would imagine that most people would learn to use this software very quickly.	4.4	0.74
8	I found this software very cumbersome/awkward to use.	2.1	1.05
9	I felt very confident using this software.	4.2	0.73
10	I needed to learn a lot of things before I could get going with this software.	2	0.77

Table 2. Summary of findings of the employee perception on the system's usability.

11. CONCLUSION

The development and evaluation of NumWorld, a gamified learning application, have demonstrated the potential of integrating game-based elements into educational environments to enhance the understanding of number systems. Through the use of interactive materials, quizzes, and gamification features such as leaderboards and badges, NumWorld has succeeded in making the learning process more engaging and effective for users. The feedback from the user survey indicates a high level of user satisfaction, with most respondents finding the application intuitive, easy to use, and effective in aiding their learning. The mean scores for user confidence and the likelihood of frequent use were particularly high, underscoring the application's positive reception.

Despite these successes, the survey also highlighted areas needing improvement, such as the complexity of the software and the initial learning curve faced by some users. These insights provide valuable guidance for future enhancements to ensure the application meets the diverse needs of all learners.

12. RECOMMENDATIONS

Based on the findings and user feedback, several recommendations are proposed to further enhance the effectiveness and user experience of NumWorld:

1. Simplify User Interface and Navigation: To address concerns about unnecessary complexity and the initial learning curve, efforts should be made to streamline the user interface. Simplifying navigation and reducing the number of steps required to access key features can help make the application more user-friendly, especially for beginners.

2. Enhanced Tutorial and Support Resources: Providing more comprehensive tutorials and support resources can help users who may need additional assistance. This could include step-by-step guides, video tutorials, and an in-app help feature to address common issues and questions.

3. Customization and Personalization Options: Incorporating more customization options, such as adjustable difficulty levels and personalized learning paths, can cater to users with different skill levels and learning preferences. This can help maintain engagement and motivation by ensuring the content remains challenging yet achievable.

4. Regular Updates and Content Expansion: Continuously updating the application with new content, features, and improvements based on user feedback will keep the learning experience fresh and engaging. Expanding the range of number system topics covered and introducing new game elements can further enhance the educational value of the application.

5. Incorporate Social and Collaborative Learning Features: Adding features that promote social interaction and collaboration, such as discussion forums, peer challenges, and group projects, can enhance the learning experience. These features can foster a sense of community and provide additional motivation through peer support and competition.

6. Rigorous Testing and Quality Assurance: Ongoing testing and quality assurance are crucial to maintaining the application's performance and reliability. Regularly scheduled updates and thorough testing of new features can help identify and resolve any issues promptly, ensuring a smooth and seamless user experience.

13. ACKNOWLEDGMENTS

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