Enhancing personal financial management skills through a machine learning-powered business simulator

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Abstract

Effective personal financial management is a critical life skill for all individuals, irrespective of their profession. A survey conducted among university students in Ukraine revealed a lack of sufficient financial literacy and highlighted the need to incorporate personal finance education into curricula. Business simulators present a promising solution to bridge this gap. This paper introduces a novel web-based business simulator equipped with machine learning capabilities to facilitate the development of personal financial management skills. The methodology for utilising the simulator, including its content, objectives, formats, methods, and tools, is elucidated in detail. The key features and sections of the simulator are described, along with the specific personal finance management skills it aims to cultivate. To enhance the simulator's effectiveness, elements of machine learning, particularly reinforcement learning, have been incorporated. The simulator is designed to cater to a wide audience, from school-aged children to adults, and can be integrated into economics courses at both secondary and tertiary education levels in Ukraine. The paper concludes with a discussion on the future prospects of using such simulators to develop managerial and financial competencies among students from diverse specialities.

Keywords

personal financial management, business simulator, machine learning, reinforcement learning, financial literacy

1. Introduction

Personal financial management is a vital skill that everyone should possess, regardless of their profession or background. It involves the effective management of one's financial resources, including income, expenses, savings, investments, and debts.

The importance of developing personal finance competency has been widely acknowledged in international research. Lusardi [1] discussed the influence of financial literacy on the well-being of people worldwide and the need to recognise it as a fundamental right and universal need. Lusardi et al. [2] demonstrated that 30–40% of retirement wealth inequality in the USA is associated with the level of financial literacy alone. Urban et al. [3] concluded that high school financial literacy courses have a significant impact on lower default rates and better credit scores.

The use of business simulations in education has become increasingly common, with applications ranging from practical training, such as flight or combat simulations, to economic, managerial, and financial domains. Researchers have studied the pedagogical significance of this technology-enhanced educational method. Hernández-Lara et al. [4] concluded that business simulations have a positive impact on generic competencies, while Farashahi and Tajeddin [5] confirmed their effectiveness in a comparative study. The evolution of technologies has enabled the development of immersive, attractive,

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and highly functional business simulations for various use cases, from elementary schools to lifelong learning establishments. Korgin [6] provided evidence of the effectiveness of simulation games for improving basic arithmetical operations literacy in children, while Palan [7] studied the criteria and approaches for selecting business simulation software for asset market experiments in higher education.

The analysis provides evidence of the effectiveness of using business simulations in education and the need for further development of business simulations for economic and financial literacy development, assessment, and the study of their behavioural aspects.

The *purpose of this article* is to describe the methodology for using a business simulator with machine learning elements to develop personal finance management skills.

2. Results

An analysis of existing simulators [8, 9] revealed that most simulation software is designed for specific areas of finance in countries with developed financial markets. Based on these findings, this work presents an experiment in developing a more generalised simulator for countries with less developed financial instrument markets.

Consequently, the authors developed a web-based business simulator [10, 11, 12] to foster personal finance management skills. The methodology for using this simulator, which incorporates machine learning elements, is presented in the following sections.

The proposed methodology encompasses the purpose and content of the application, as well as the forms, methods, and tools employed. It is focused on the expected outcome: improved personal finance management skills through the use of a business simulator with machine learning elements.

The purpose of using the simulator is to develop personal finance management skills, while the content involves enhancing the teaching process of normative disciplines through its integration.

The methodology includes two key methods for utilising the simulator:

1. *Adaptive learning*. The simulator creates a game-like process, known as the examination cycle, in which users encounter problems corresponding to their current competence level at each stage. As users progress through the simulation, they gain access to new personal finance management tools that could not be effectively used at previous competence levels. This approach requires users to iteratively master increasingly complex knowledge, skills, and abilities, and apply them in situations resembling real-life scenarios. Users can explore previously unfamiliar tools and situations or those of additional interest to them, considering their life cycle stage, field of activity, or current problems and interests.
2. *Situational modelling*. The simulator is based on realistic simulations of common and specific situations in personal or family finance management. It begins by modelling the creation of a diversified currency and financial basket storage forms, then progresses to more complex tools, such as credit and deposit operations with varying time parameters, payment schedules, and provision forms. The simulation's realism is ensured by the presence of probabilistic events with positive or negative impacts of different monetary values on the user's personal finances. Non-financial investment transactions are introduced as the next step in familiarising users and developing their competence in personal finance management.

The main forms of conducting training sessions using the simulator within the framework of this methodology include:

- Introductory classes for teachers and facilitators on the simulator's functionality, modes, features, analytical capabilities, and means of scientific research on the effectiveness and adaptability of the user competence development process;
- Autonomous and group independent work with the simulator, aimed at both independent in-depth or convenient pace learning through the training and game plot, and joint learning activities of user groups and facilitators, with or without competitive elements;

- In-depth analysis of simulator situations can take place in face-to-face or remote formats with individual students or groups, focusing on additional elaboration of situations, behavioural and psychological aspects, or financial instruments that cause difficulties, misunderstanding, or attract additional user interest.

The tools for developing personal finance management skills provided in the proposed methodology include computers, smartphones, and tablets with Internet access, the business simulator with machine learning elements, and teaching materials.

The expected result of the proposed methodology is the formation of personal money management skills at a high level and the acquisition of skills to successfully apply the business simulator with machine learning elements to perform practical work.

Within the framework of this methodology, different forms and methods of using the simulator are offered, such as:

- Organisation and development of the simulator to develop personal finance management skills;
- Sessions using the simulator to simulate socio-economic situations corresponding to the lesson topic;
- Organisation of thematic economic training using the simulator;
- Visualisation of economic and behavioural concepts;
- Using the simulator as a means of targeted in-depth problem-based learning;
- Using the simulator as a means of organising assessment.

The main features of the simulator, presented in different sections (figure 1), include:

1. Current account management options.
2. Savings management options.
3. Deposit management options.
4. Credit management options.
5. Non-financial investment management options.
6. Information on changes in current accounts that have occurred in the last week.
7. Analytical information on the dynamics of changes in current account funds, savings, and investments.
8. Information on current exchange rates.
9. List of recent transactions made on current accounts.

The simulator facilitates the formation of knowledge, skills, competencies, and personal attitudes towards:

- Using a diversified list of currencies.
- Forming a widely-acknowledged standard of emergency savings and assessing readiness for longer-term investment.
- Using basic saving and investment instruments available in a wide range of countries, such as deposits (deposit certificates), real estate, and business investments, and understanding their specific characteristics.
- Debt management and forming a personal behavioural attitude towards using debt as a constructive investment leverage.

To enhance the effectiveness of the simulator, machine learning elements, particularly reinforcement learning, have been applied. Reinforcement learning (RL) is a type of machine learning in which an agent directly examines environmental data, receives rewards, and sets policies for optimal action (figure 2). The goal of RL is to find the optimal policy that maximises the expected amount of future rewards [13].

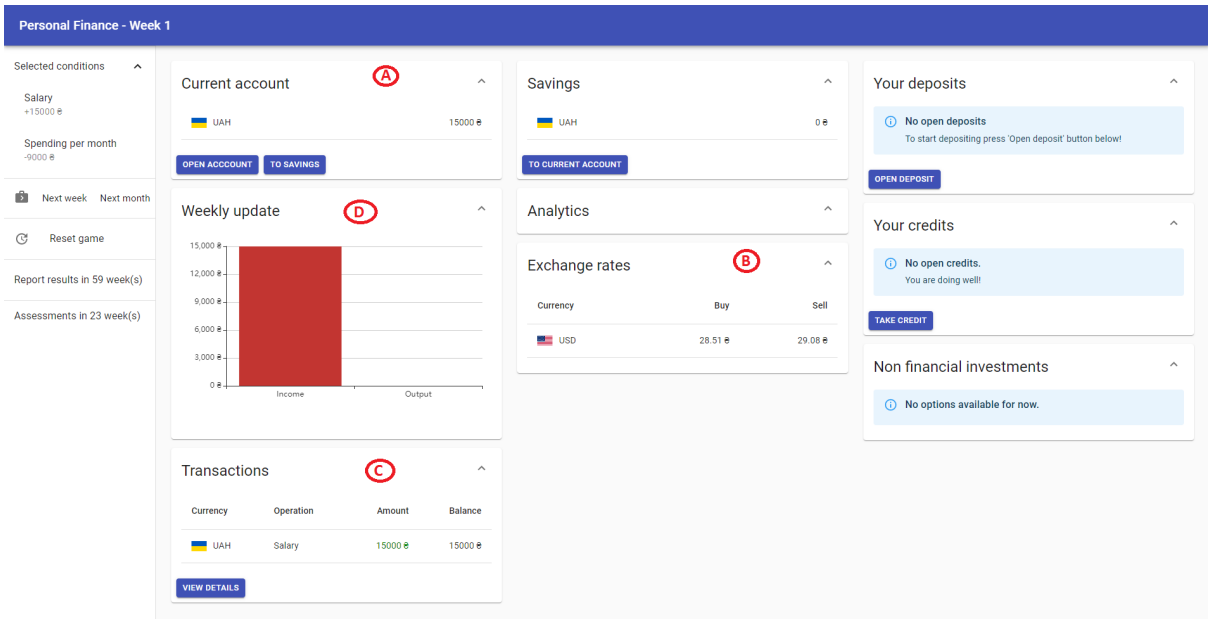

Figure 1: Business simulator.

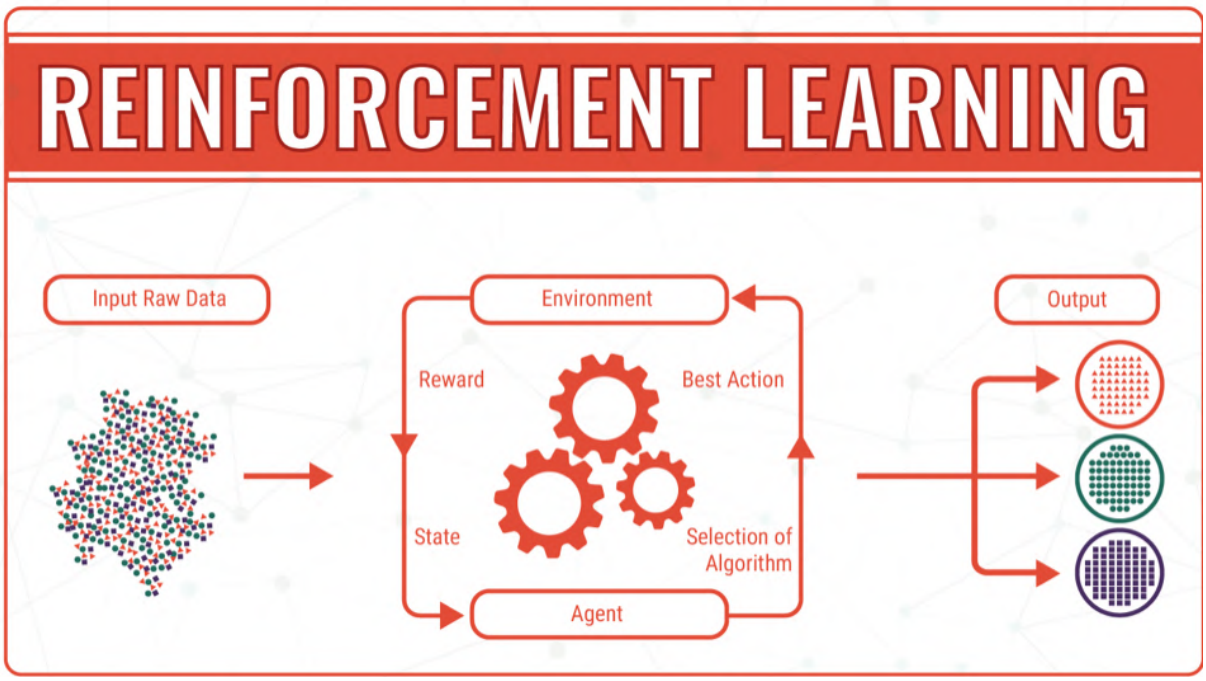

Figure 2: The principle of operation of the model of training with reinforcement [13].

$$Q^{new}(S_t, A_t) \leftarrow (1 - \underbrace{\alpha}_{\text{learning rate}}) \cdot \underbrace{Q(S_t, A_t)}_{\text{current value}} + \underbrace{\alpha}_{\text{learning rate}} \cdot \Big(\underbrace{R_{t+1}}_{\text{reward}} + \underbrace{\gamma}_{\text{discount factor}} \cdot \underbrace{\max_a Q(S_{t+1}, a)}_{\text{estimate of optimal future value}} \Big)$$

new value (temporal difference target)

Figure 3: Q-learning algorithm.

One of the algorithms used in reinforcement learning is Q-learning, which aims to learn a strategy that informs the agent about the best action to perform in a particular state S. The algorithm contains elements such as the reward received (r_t), the learning pace (α), and the depreciation ratio (γ) (figure 3).

The open-source library SharpRL [14] was chosen to provide the basic functionality for developing a reinforcement learning environment based on the Q-learning algorithm. The program for defining personal financial strategies is a console application that involves setting certain parameters, such as the number of simulation passes in training mode, the number of simulations in policy adherence mode after training, the duration of the simulation in weeks, and the user's monthly income and expenses in a specific currency.

Experiments were conducted to determine the optimal ratio of initial parameters, and it was found that the best results were obtained when the number of simulation passes in both training and policy adherence modes was close to 1000. Increasing these figures did not significantly improve the results (figure 4).

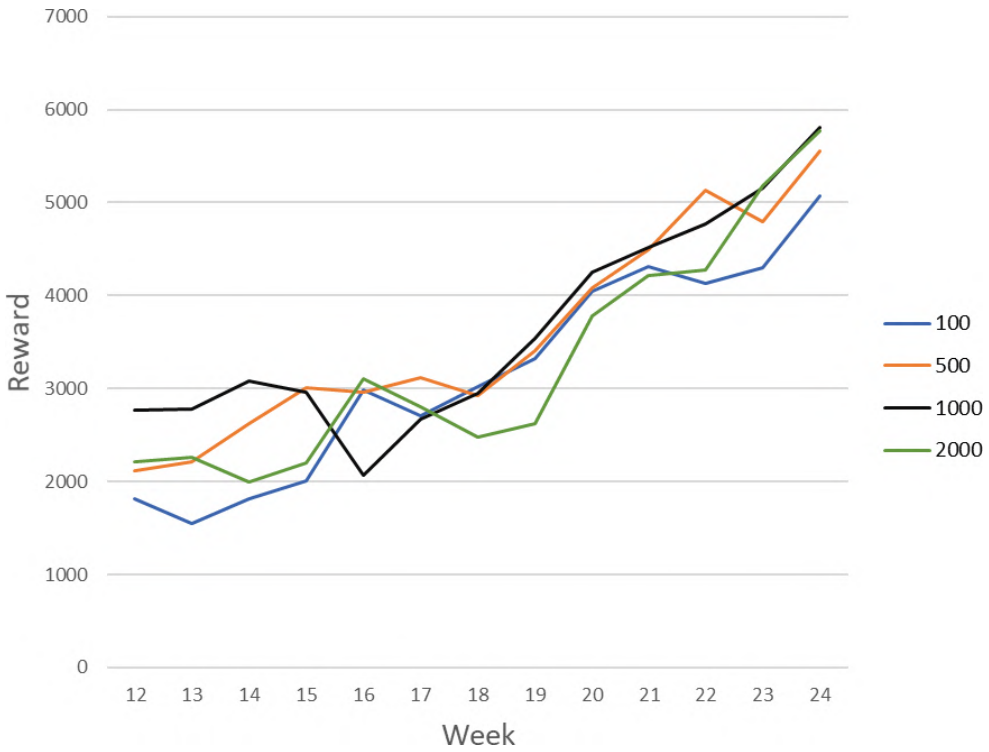

Figure 4: Results with different number of epochs of training in the mode of adherence to the trained model.

To test the trained model, the results of the system were compared with the average results of real users in the developed simulator over a 54-week period. It was found that the system consistently outperformed the average user results (figures 5, 6, 7, 8).

The graphs depicting the reinforcement learning model results exhibit jumps, particularly when higher incomes and a large difference between income and expenses are involved. This is due to the specific rules described to train the model, ensuring that the virtual agent system follows the best path. For example, if an agent opens a 3-month deposit, the deposit will be closed automatically after this period, significantly affecting the user's reward for that week. However, the system learns and "understands" where to invest or save, leading to sharp increases in performance, as evident in the graphs. Such behaviour is not observed in the graphs representing real user results, indicating users' lack of awareness of effective personal finance management strategies within the developed simulator.

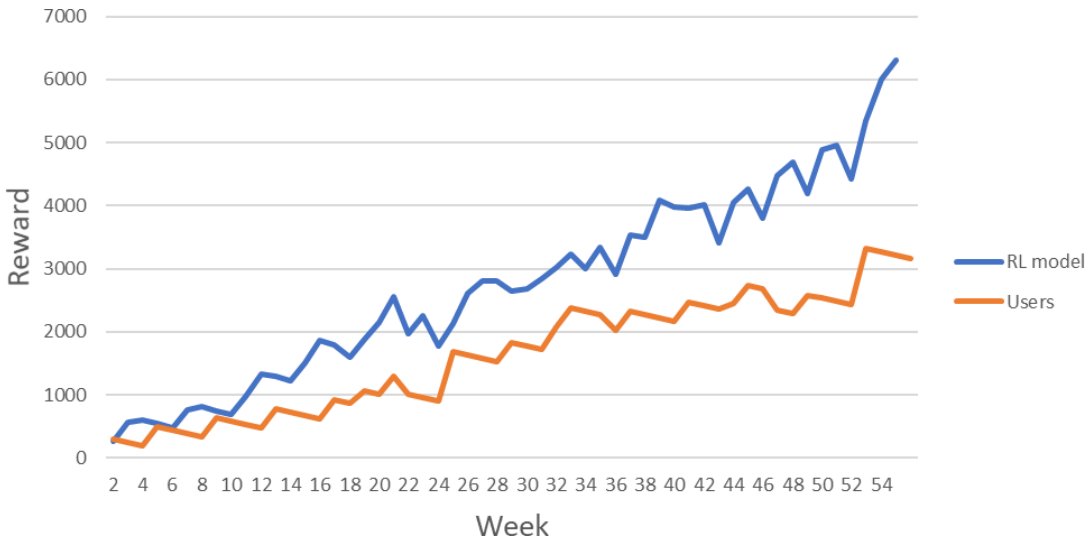

Figure 5: Comparison of model and user results with parameters of UAH 10,000 income and UAH 6,000 costs.

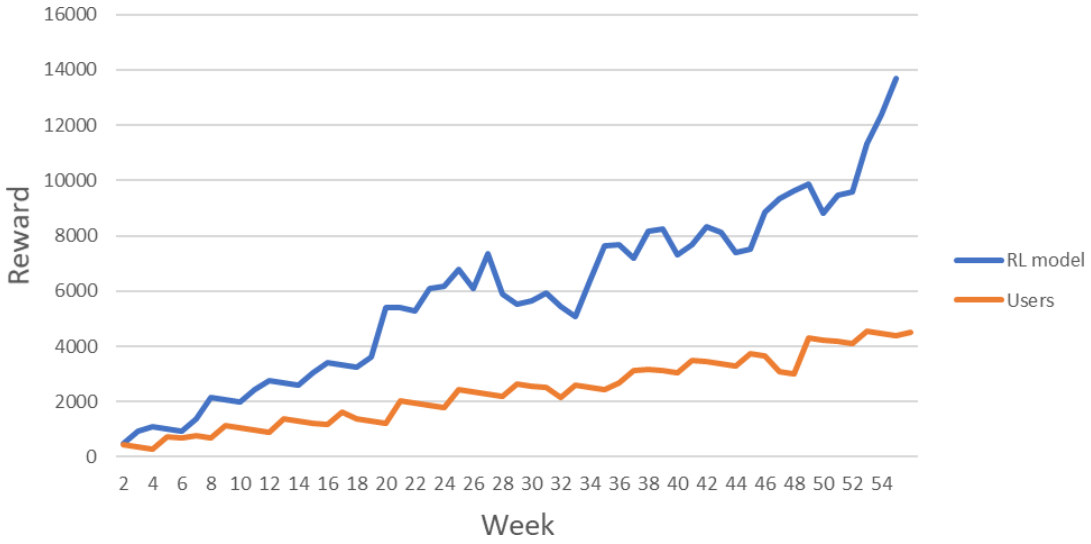

Figure 6: Comparison of model and user results with parameters of UAH 15,000 income and UAH 9,000 costs.

3. Conclusions

Economic processes are a new topic for research into the possibilities of applying the full potential of machine learning. Scientists worldwide are making initial attempts to reproduce such processes programmatically to use artificial intelligence to find solutions and answer various economic questions.

The proposed developed software package consists of two parts: a personal finance management simulator and a system for determining effective financial strategies, which utilises reinforcement learning opportunities.

The simulator can be used in the future to teach elements of personal finance management to people who are not sufficiently knowledgeable in this field. Moreover, the web application can be useful even for school-aged children, complementing the educational process within economic courses not only in higher education institutions but also in secondary education institutions in Ukraine.

When constructing a methodology for using a business simulator with machine learning elements to develop personal finance management skills, it is advisable to consider various types, scopes, methods of placement, and purposes of using business simulators. The use of a business simulator with machine learning elements is expedient and contributes to an increase in the efficiency of the educational process,

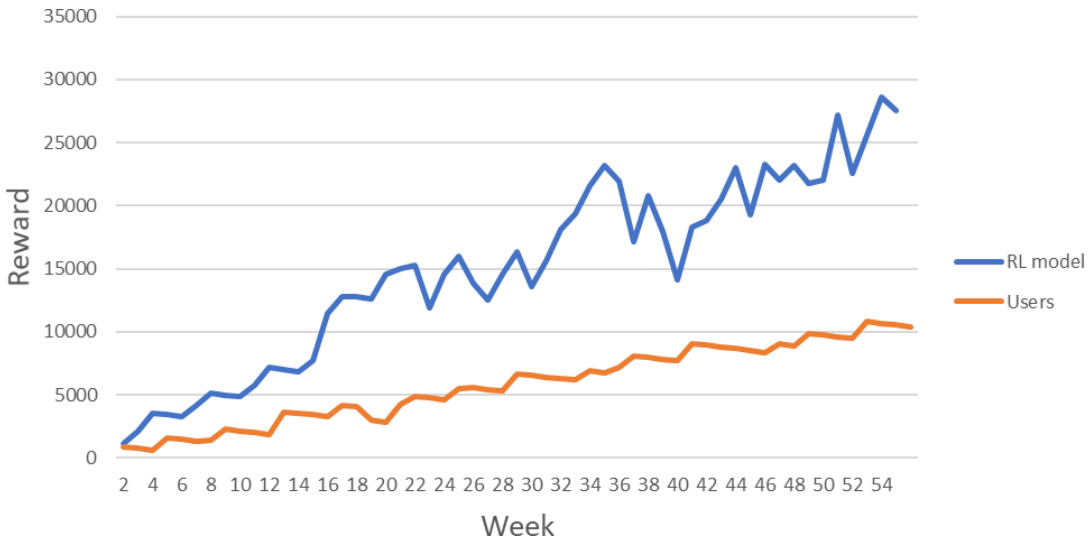

Figure 7: Comparison of the results of the model and users with the parameters of UAH 30,000 income and UAH 15,000 costs.

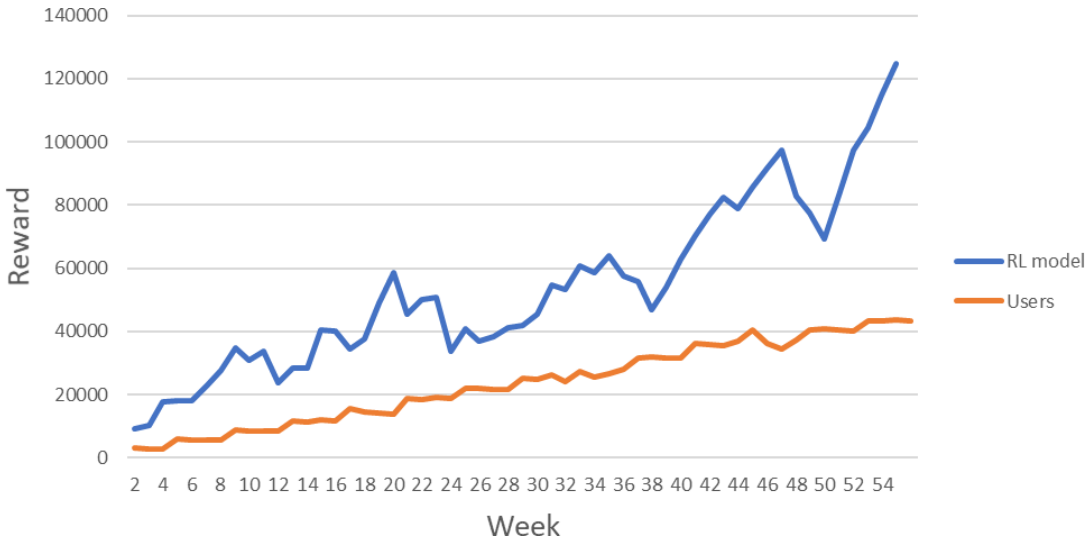

Figure 8: Comparison of the results of the model and users with the parameters of UAH 100,000 income and UAH 30,000 costs.

the formation of personal finance management skills, and the development of a steady cognitive interest in students' educational activities. The application of the author's methodology will improve and supplement the educational process in higher education by including a business simulator with machine learning elements.

Additionally, prospects for further study include the selection of different simulators of this type, the possibility of using such simulators to develop managerial and financial competencies of students in various specialities, as well as the development of an appropriate methodology and testing its effectiveness. In the future, the authors plan to develop guidelines for teachers on using a business simulator with machine learning elements to develop personal finance management skills in the educational process of higher education.

Declaration on Generative AI: During the preparation of this work, the authors used Claude 3 Opus in order to: Improve writing style, Abstract drafting. After using this service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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