U.Porto Journal of Engineering, 8:1 (2022) 12-22
ISSN 2183-6493
DOI: 10.24840/2183-6493_008.001_0003

Received: 28 October, 2021
Accepted: 5 December, 2021
Published: 16 February, 2022

Gamification of Open Inquiry-based Learning of Blockchain Technologies

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Abstract
Inquiry-based Learning is an efficient learning method. This method is applied in many science courses. It is a research-oriented method which awakens personal curiosity of learners. Learners are motivated intrinsically, and they learn by research. Wide research areas can be investigated using Inquiry-based Learning. It can be applied to all learning areas. In the literature, Inquiry-based Learning is applied to science education. In this paper, Inquiry-based Learning is applied to a software engineering course. The application is novel because the area is a non-science area. Cryptocurrencies, which are applications of blockchain technologies, are selected as the research area. Research is done by students freely. Results of research are combined and shared among students. Students are assessed. Inquiry-based Learning is applied in a least structured way. In other words, open Inquiry-based Learning is applied. To empower it, gamification is used. A methodology for open Inquiry-based Learning is presented. The effect of gamification is measured.

Author Keywords. Inquiry-based Learning, Gamification, Gamified Learning, Open IBL, Software Engineering Course, Cryptocurrency Technologies.

Type: Research Article

1. Introduction

Learning can start with questions. In fact, this method of learning is used by scientists implicitly. This method is effective because personal curiosity awakens and motivates learning. The method can be used in all areas of learning, and it is known as Inquiry-based Learning (IBL). IBL enhances student engagement, self-confidence, learning performance, and research skills.

IBL is well-suited for science education because IBL depends on research. However, it can be applied to all areas. In this work, IBL is applied to a software engineering course in a least structured way. In other words, open IBL is applied to the course. IBL is an active process because learners act as scientists. Learners control their learning process. The control is at the maximum level in open IBL.

Real-world problems are good candidates for IBL. However, implementation of real-world problems is not easy in classroom settings. Therefore, simulations of real-world problems can be used in IBL. Moreover, tools, frameworks, and environments can be designed and used. In this work, a developing area in computer science is used for IBL. Blockchain technologies are new and attractive for many people. In that area, there are numerous cryptocurrencies, and this is an interesting area for research.

Using game elements in applications is called gamification. In learning, gamification can also be used to increase motivation. IBL and gamification are merged in many applications. Game elements are employed in different stages of IBL. IBL supports learning performance. Gamification supports learning performance. Usage of both doubles learning performance. In the paper, open IBL is employed in the blockchain research area. Since open IBL is less structured, its implementation is more problematic than other IBL implementations. Gamification can be used to calibrate open part of the IBL.

In this work, open IBL is applied in a software engineering course. The course is about blockchain technologies. Blockchain technologies are closely related to cryptography (Antonopoulos 2017). Cryptocurrencies are implementations of blockchain technologies. In the paper, cryptocurrency area is investigated in an open IBL approach. The open IBL approach is strengthened with gamification. This is a novel approach because open IBL is applied to technological data.

The rest of the paper is structured as follows. In the next section, related work is given. Then, the methodology is described. In the following sections, applications of the methodology and results are presented. Lastly, discussion and conclusion are stated.

2. Related Work

People learn and adapt to environment. Learning is a very important activity in life. Therefore, efficient learning mechanisms are valuable for humankind. If learners manage their learning activities, learning may become more efficient and effective. This type of learning is known as Self-regulated Learning (SRL) (Kravcik and Klamma 2012). One type of SRL is IBL (Mikroyannidis, Okada, and Scott 2013). In IBL, learning is initiated by questions, and learners act like scientists. IBL triggers personal curiosity of learners. Learners gather information, develop ideas, make discoveries, and build knowledge (Levy and Petrulis 2012). Hence, they contribute to their personal development. IBL is not a teacher-centered approach. On the contrary, it is a learner-centered approach (Gormally et al. 2009). Learners gain self-confidence and improve research skills (Kienzler and Fontanesi 2017).

In Spronken-Smith (2012), a review on IBL can be found. Student engagement, higher-order learning outcomes, and academic achievement can be improved by IBL. IBL combines teaching and research. IBL increases interaction and enjoyment. In Spronken-Smith (2012), key attributes of IBL are determined. Learning is an active approach and is stimulated by inquiry. IBL is a learner-centered approach where learning is self-directed. Examples of IBL show that it can be applied at all stages of the disciplines of higher education. IBL usage in numerous disciplines of higher education is reported in Aditomo et al. (2013). The usage ranges from small to large classes in undergraduate and graduate programs where research is intensive or not. In Pedaste et al. (2015), core features of IBL are identified in a systematic literature review. At the beginning, all the phases and sub-phases of IBL are determined. Afterwards, required features are identified for the phases. As a result, a synthesized framework is provided for the whole IBL process.

In Spronken-Smith et al. (2011), cases of IBL are reviewed to determine the factors that affect its usage. The attributes of teachers, course designs, departments and institutes are identified for effective use of IBL. IBL is well suited for real-world problems. Scientists study real-world problems and learn through their research. Likewise, learners in IBL act as researchers and learn the subjects. However, implementation of real-world problems is difficult in education. Therefore, simulations of real-world problems are employed to apply IBL. In Tsai (2018), an electricity problem from daily life is simulated and used in IBL. In Buckner and Kim (2014), students are engaged with real-world problems through simulations.

In Hsu, Lai, and Hsu (2015), scaffolding in IBL is discussed. Three versions of scaffolding are compared. The goal-oriented one is more effective than teacher-led and deconstructed versions of scaffolding. The key features of goal-oriented scaffolding are an advanced organizer, deconstruction of complex tasks and evaluation of the process. In Dorier and García (2013), a large-scale implementation of IBL is analyzed to determine conditions to use IBL effectively. The analysis is organized in four levels: discipline, pedagogy, school, and society. In Madhuri, Kantamreddi, and Prakash Goteti (2012), a laboratory course in engineering chemistry is designed using IBL approach. The results show a significant improvement in learning performance. In Panasan and Nuangchalerm (2010), IBL and project-based learning are compared in the fields of learning achievement, analytical thinking and science process skills. Results show that both are effective and efficient. In Gormally et al. (2009), IBL is applied in a lab course. Science literacy and research skills of students are improved greatly.

Learning environments are created with tools to enhance learning performance. Learners can completely control their learning using learning environments. In Mikroyannidis, Okada, and Scott (2013), a learning environment is introduced to improve IBL. In the learning environment, students learn to collaborate and investigate. In Tsai (2018), a computer-simulated environment is developed to do scientific inquiry for IBL. The environment has positive effects on learners to increase their knowledge significantly. In Levy, Aiyegbayo, and Little (2009), a learning activity management system is used to create learning designs for IBL. Teachers or students can create learning designs for knowledge creation. In Apedoe and Reeves (2006), digital libraries are used to design and implement IBL in courses. Digital libraries support intellectual curiosity, creativity, and problem-solving skills. Students build different interpretations of real-world data using digital libraries. In Buckner and Kim (2014), a framework is presented to integrate information and communications technologies with IBL in classroom settings. The effectiveness of the framework is tested in various countries. In Oliver (2008), a web-based tool is developed to support IBL. The tool is characterized by meaningful contexts, feedback, strong learning scaffolds, support, and efficient administration. The tool increases problem-solving experiences of students and supports student engagement. In Mulder, Lazonder, and De Jong (2014), a computer simulation is used to create models by consulting heuristic worked examples. Heuristic worked examples enhance models created for IBL. In Maaß and Doorman (2013), a complex model for IBL is presented for large-scale implementation. The model is used to change ordinary teaching in various contexts.

IBL can be described as a workflow (Pedaste et al. 2015). The workflow has 5 distinct phases. It starts with orientation and ends with discussion. In between, there are conceptualization, investigation, and conclusion phases. Conceptualization, investigation, and discussion phases can also be divided into sub-phases. Discussion phase can be present at any time through the workflow as well as at the end of the workflow.

Gamification is the usage of game elements in applications (Alhammad and Moreno 2018). Gamification can be applied to IBL. In Dicheva et al. (2015), a review is made on the application of gamification to education. The effectiveness of game elements in education is examined. Which game elements are effective in which educational contexts are reviewed. In Mikroyannidis, Okada, and Scott (2013), virtual badges are rewarded to students in personal learning environments. Students get badges when they reach certain milestones in the workflow. Virtual badges shared in social networks increase student motivation. In Gao, Fabricatore, and Lopez (2019), game elements used in IBL are reviewed. Various game elements are used to support core features of IBL. Learning process, environment creation, and progressive guidance are empowered. In Tsai (2018), the IBL environment is supported with game elements such as points and story. Game elements are used to increase the intrinsic motivation of students (Garris, Ahlers, and Driskell 2002). In this work, gamification is used to strengthen IBL in the application to a software engineering course. In Zion et al. (2004), the dynamic nature of IBL is investigated. Learning is a process where changes occur during research. In this work, gamification is applied in an iterative way, which yields changes in each iteration.

Cryptocurrencies are digital assets based on blockchain technology (Härdle, Harvey, and Reule 2018). Currently, there are 3589 cryptocurrencies ("CoinMarketCap", n.d.). In Marella et al. (2020), the underlying technological attributes of cryptocurrencies, which drive trust, are analyzed based on Bitcoin. The two properties, immutability and openness, are unique to cryptocurrencies compared to traditional financial instruments. Openness drives transparency, and immutability drives accountability. Transparency is the main element for creation of trust. In Irresberger et al. (2021), an empirical overview is provided for cryptocurrencies. Why a few cryptocurrencies dominate the market is analyzed based on a framework. The key elements of the framework are scale, security, and adoption. A review of the market for cryptocurrencies can be found in Corbet et al. (2019). In Li et al. (2019), characteristics of cryptocurrencies are presented using a representative set of cryptocurrencies. Technical and business characteristics are provided for practitioners. An important technical characteristic is consensus algorithm. Proof of Work (PoW), Practical Byzantine Fault Tolerance (PBFT) and Proof of Stake (PoS) are the mostly used consensus algorithms. In Li and Whinston (2020), features of cryptocurrencies and their economic implications are investigated. The three cryptocurrencies which are Bitcoin, Ether, and XRP are used in the investigation because they have the highest market values. The differences among the cryptocurrencies are extracted according to their identity management, coin supply, and consensus algorithms. In this work, the richness of cryptocurrencies enabled it to become the research area for open IBL implementation.

IBL is a student-centered approach, and it is directed by students. In the process, teachers guide students. The guidance level of students differs in versions of IBL. Guidance can be in 4 levels (Gao, Fabricatore, and Lopez 2019). These levels determine types of IBL. In open IBL, guidance is at minimum level, and students guide themselves. Students build research questions, define inquiry methods, and execute the IBL process. In guided IBL, while teachers provide research questions, methods are determined and executed by students. In structured IBL, teachers provide methods as well as research questions. Students carry out research. In confirmation IBL, students are guided in all stages of the process. IBL is implemented in science courses. In this work, open IBL is applied to a software engineering course, which is a non-science course. Implementation of open IBL is difficult because there is minimum guidance by teachers. For this purpose, gamification is used to empower open IBL.

3. The Methodology

Open IBL is applied using a methodology to a software engineering course. The methodology is depicted in Figure 1. Prediction is at the center of the methodology. First, students do their research. Then, findings are collected, shared, and predictions are made. Finally, assessment is realized. These phases are repeated a few times as cycles. Throughout the cycles, gamification is applied using game elements. Each cycle is also a game element “competition”.

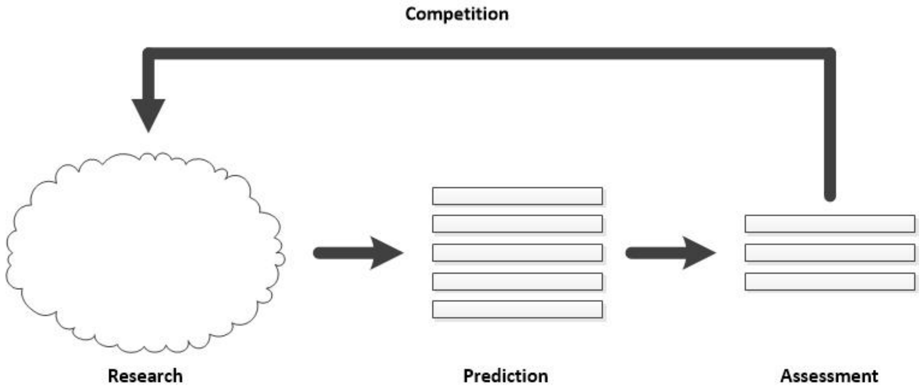

Figure 1: Methodology

A competition has 3 phases as the following:

- Phase 1: Research Phase
- Phase 2: Prediction Phase
- Phase 3: Assessment Phase

At the base of the methodology, there are questions and answers to those questions. In other words, question-answer pairs are extracted through research, and they form knowledge to be shared. The aim of the methodology is to find the best question-answer pairs. For this purpose, rules are determined at the beginning of the methodology. The rules are called qualification rules. Qualification rules should motivate students to extract the best question-answer pairs in the research area.

At the beginning of the methodology, the research area and the qualification rules are determined:

- Research area is determined
- Qualification rules are arranged

In this work, the research area is cryptocurrencies. Qualification rules are arranged to maximize the quality of questions. In the research phase, a different subject is assigned to each student. Each student prepares a few qualified questions according to the qualification rules. They also prepare their answers. According to the quality of questions, students are graded. Therefore, students are motivated to prepare perfect questions. In the prediction phase, the prepared questions and answers are collected and shared with other students. Each student predicts the questions which will be asked in the assessment phase. The predictions are made according to the qualification rules determined at the beginning of gamification. The qualification rules are used to measure the quality of questions. The predictions are considered in the classes and discussed with students. Correct predictions are the sources of game elements “points” and “leaderboard”. Each student can follow his/her points and his/her rank on the leaderboard. In the assessment phase, an exam is arranged with selected questions. Questions are selected according to the qualification rules by the teacher.

In Table 1, competitions and cryptocurrencies are shown. In the course, there are 11 registered students. Gamification is applied in 3 competitions. For each competition, 2 cryptocurrencies are determined for each student. Cryptocurrencies are categorized as X-category and Y-category cryptocurrencies.

	Competition 1		Competition 2		Competition 3	
Student	**X-category**	**Y-category**	**X-category**	**Y-category**	**X-category**	**Y-category**
01	Metal	Aeternity	SureRemit	Novacoin	Scorum Coins	Gnosis
02	Aragon	Dash	Feathercoin	NavCoin	OmiseGO	Syscoin
03	Primecoin	Dogecoin	Augur	Dock	Waltonchain	Credits
04	Steem	ICON	Aurora	SafeInsure	Factom	Datum
05	Nano	Ontology	Siacoin	Shift	NuBits	Kyber Network
06	Decred	BitShares	GET Protocol	Basic Attention Token	ClearCoin	Civic
07	Enjin Coin	Verge	Eristica	NEM	Aventus	Lisk
08	0x	Peercoin	SafeCoin	Ravencoin	Iconomi	Bancor
09	TRON	Binance Coin	Uniform Fiscal Object	PIVX	Dreamcoin	MaidSafe
10	Litecoin	Tezos	Bytecoin	Sapien	Qtum	Edgeless
11	Golem	Nxt	Digitex	Komodo	MicroMoney	Enigma

Table 1: Competitions and cryptocurrencies

Gamification is applied in the methodology, and its effect on learning is measured. For this purpose, a control group is formed. Actually, the control group is not formed in students. The research area is divided randomly into two groups as experimental and control groups. X-category of the cryptocurrencies is the experimental group, whereas Y-category of the cryptocurrencies is the control group. Gamification is applied to only X-category cryptocurrencies. Therefore, the learning performance of X-category compared to Y-category shows the effect of gamification in learning.

Each student will prepare 2 questions for the assigned cryptocurrencies in each competition. Answers to the questions will also be prepared. Each competition has 3 phases. Each phase will last for 1 week. The details of the phases are the following:

Phase 1: Research Phase

- Each student will prepare 2 questions about each of the assigned cryptocurrency.
- Each question will be graded with the following qualification rules:
    - Question should be related to the assigned cryptocurrency.
    - Question should be related to an interesting property of the assigned cryptocurrency.
    - Answer should be correct.
    - Question should be short.
    - Answer should be short.

In the Research Phase, students prepare question-answer pairs for the assigned cryptocurrencies. In other words, for each competition, there are 2*n question-answer pairs, where n is the number of students. Of these pairs, n pairs are in X-category and the other n pairs are in Y-category. These 2*n question-answer pairs are shared before the Prediction Phase. At this time, students do not know these 2*n question-answers are correct or not. However, they should select 5 question-answer pairs from X-category questions, which will be asked in the exam of the competition.

Phase 2: Prediction Phase

- In the Assessment Phase, an exam will be conducted. In the exam, there will be 5 questions from X-category and 5 questions from Y-category.
- The students will make predictions from X-category cryptocurrencies according to the qualification rules.

- Each student will predict 5 questions from X-category cryptocurrencies. Each student will predict which questions can be asked in the exam. If all predictions are realized, the student will get full points from this phase. If some of them are realized, the student will take points proportionally.

In the Prediction Phase, students do their predictions on only X-category question-answer pairs. In other words, they do predictions on gamified cryptocurrencies. They will attend the exam in the Assessment Phase without knowing the correctness of the questions and answers. In the exam, the best questions will be asked according to the predetermined qualification rules. These rules are known by the students.

Phase 3: Assessment Phase

- In the Assessment Phase, an exam will be conducted. In the exam, there will be 5 questions from X-category and 5 questions from Y-category.
- The questions will be selected according to the qualification rules by the teacher.
- The most interesting questions will be selected. In other words, there can be 2 questions, 1 question or 0 questions from each cryptocurrency.

Students attend to the exam without knowing the correctness of the questions and the answers. They are responsible for all the 2*n questions. After the Assessment Phase, the asked question-answer pairs are discussed in the class.

4. Experimental Results

Open IBL is applied in the course SE427 Blockchain and Cryptocurrency Technologies. The course is a technical elective course and is taught in Software Engineering Department at Atilim University. The course is composed of midterm, final, project and assignments. Open IBL is used for the assignment part of the course. Table 2 shows the competition results. 11 students did research about given cryptocurrencies in competitions. The column P under the heading competition shows the number of correct predictions of students in the related competition. Column X under the heading competition shows the exam results for X-category cryptocurrencies. Similarly, column Y shows the exam results of Y-category cryptocurrencies. Under the heading total, the predictions and exam results are summed. The last column shows the proportion of X and Y columns. In other words, it is the division of X-category exam results with the Y-category exam results.

	Competition 1			Competition 2			Competition 3			Total			Result
Student	P	X	Y	P	X	Y	P	X	Y	P	X	Y	X/Y
01	1	35	37	0	30	32	2	40	35	3	105	104	1.01
02	3	40	20	2	42	20	2	36	25	7	118	65	1.82
03	4	45	45	3	40	46	3	50	45	10	135	136	0.99
04	1	35	20	0	25	17	1	20	32	2	80	69	1.16
05	2	45	40	1	40	20	0	35	25	3	120	85	1.41
06	1	38	45	2	35	25	3	45	35	6	118	105	1.12
07	0	47	30	2	20	35	1	47	40	3	114	105	1.09
08	2	50	43	3	40	35	1	45	35	6	135	113	1.19
09	3	35	30	3	39	18	2	35	15	8	109	63	1.73
10	1	40	25	2	25	15	4	45	30	7	110	70	1.57
11	2	45	40	1	40	40	2	50	41	5	135	121	1.12
Average	1.82	41	34	1.73	34	28	1.91	41	33	5.45	116	94	1.23

Table 2: Competition Results

In each competition, an exam was made. There are 5 X-category questions and 5 Y-category questions. In other words, there are 5 gamified questions and 5 non-gamified questions. Each question is 10 points so that each exam is over 100. Each student can take at most 50 from X-category (column X) and at most 50 from Y-category (column Y). For example, Student 05 did 2 correct predictions in the first competition, and he/she took 45 points from X-category and 40 points from the Y-category. After 3 competitions, he/she obtained 120 points form X-category and 85 points from Y-category with totally 3 correct predictions. He/she got better points from X-category. If it is compared with Y-category, the proportion 1.41 is found. This shows the dominance of X-category in the grades.

Open IBL is applied to the course. In order to determine the effect of gamification, gamification is applied to only X-category cryptocurrencies. The Y-category cryptocurrencies are not gamified. In other words, students made their predictions for X-category cryptocurrencies.

In each competition, 5 questions from X-category cryptocurrencies and 5 questions from Y-category cryptocurrencies are asked in the assessment phase. Students predict 5 questions from X-category cryptocurrencies. Predictions are discussed in classes with students to motivate them.

The result column shows the average proportion of X-category and Y-category exam results. Gamification is applied to only X-category. Therefore, the result column shows the effect of gamification in learning. According to the results, gamification affects learning performance 23% better.

5. Discussion

The application of open IBL has lasted for 9 weeks. During this period, predictions are discussed in the classes to increase student engagement. Students did their research. Moreover, they also did research about other cryptocurrencies because they wanted to check whether those questions were correct or not. In this way, they tried to understand properties of other cryptocurrencies. Their learning efficiency was increased.

In the experiment, although the number of students is small, the effect of gamification highlights itself. In future studies, it is better to repeat the experiment with an increased number of students. In the methodology, the control group is not formed in students. Instead, the research area is divided into two groups. A similar approach may be applied to other application areas. Another limitation of the work is that it is applied to undergraduate engineering students. The proposed methodology may be applied to other groups with different profiles.

Usual applications of IBL are in science courses. Science courses are related to nature. Like scientists, students do research on nature. Each research is interesting because there are plenty of things for research in nature. On the other side, technology is growing exponentially. Currently, it creates plenty of data. In the future, research on technological data will increase very much, and their research will be similar to the current nature research. Actually, this work is a step of future research on technological data.

6. Conclusion

IBL increases learning performance. In this work, IBL is applied to a software engineering course. The course is related to blockchain and cryptocurrency technologies. Cryptocurrency technology is a suitable and wide area for research. There are numerous cryptocurrencies. In the course, cryptocurrencies are investigated using IBL. Since the research area is fairly wide, open IBL is well-suited. In open IBL, all the questions are determined and investigated by students. However, this flexibility may cause students to go out of discipline. Therefore, gamification is used to calibrate the flexibility as well as to increase learning performance. Briefly, open IBL is applied to a non-science area using gamification.

For the gamification of open IBL, a methodology is presented. The methodology depends on predictions. It uses 3 game elements as competition, points and leaderboard. In gamification, 3 competitions are realized. In each competition, research, prediction, and assessment phases are passed. In the research phase, students do their research. In the prediction phase, students check other research and try to predict the best research. Correct predictions provide points to students, and students follow their ranks in the leaderboard. In the assessment phase, students are assessed with selected questions. The predictions and selections of questions are made according to the predetermined qualification rules. Briefly, a gamification methodology for open IBL is presented.

IBL is applied to science courses. In this work, open IBL is applied to a software engineering course using gamification. In order to measure the effect of gamification in the application, half of the research area is not gamified instead of grouping of students. At the assessment phases, gamified and non-gamified parts of the research area are assessed in the exams. According to the assessments, gamification increases learning performance in open IBL. Moreover, students do more research in open IBL because they need to check the correctness of other research. Therefore, student engagement is increased.

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