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Development of Blockchain Learning Game-Themed Education Program Targeting Elementary Students Based on ASSURE Model

Eunsun Choi [1], Youngmi Choi [2] and Namje Park [3,*]

[1] Major in Computer Education, Faculty of Science Education, Graduate School, Jeju National University, Jeju-si 63294, Korea; choi910624@jejunu.ac.kr
[2] Center for Creative Education, Jeju National University, Jeju-si 63294, Korea; ymchoi@jejunu.ac.kr
[3] Department of Computer Education, Teachers College, Jeju National University, Jeju-si 63294, Korea
* Correspondence: namjepark@jejunu.ac.kr; Tel.: +82-64-754-4914

Abstract: The blockchain education program based on the ASSURE model proposed in this article is of value because it can be applied in blended learning during the COVID-19 pandemic, using learning games to facilitate self-directed learning. We developed the education program in accordance with the six steps of the education design process of the ASSURE model. Firstly, we assessed learners to identify digital literacy issues of South Korean elementary students and jobs desired by them. Secondly, the objective of blockchain education was defined as improving awareness of and attention to blockchain technology by elementary students. Thirdly, gamification applied lessons were used as a teaching method, with educational media and data developed as worksheets and materials that can be used both online and offline. Fourthly, the educational contents and teaching aids were tested to evaluate the developed learning materials. Fifthly, the learning games were designed to offer rewards. Last, we designed the program to teach the principles of consensus mechanisms, private blockchain, and public blockchain. Education experts' feedback was analyzed using technical statistics and LDA-based topic modeling to assess and modify the program. The education program design approach incorporating gamification elements was effective but needed expansion in coverage to include level-based teaching elements.

Keywords: blockchain; gamification; ASSURE model; primary education; blended learning

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Citation: Choi, E.; Choi, Y.; Park, N. Development of Blockchain Learning Game-Themed Education Program Targeting Elementary Students Based on ASSURE Model. *Sustainability* **2022**, *14*, 3771. https://doi.org/10.3390/su14073771

Academic Editors: Sébastien Jacques and Abdeldjalil OUAHABI

Received: 3 March 2022
Accepted: 20 March 2022
Published: 23 March 2022

1. Introduction

Due to recent ICT breakthroughs, many innovative approaches have appeared in the educational sector [1]; the COVID-19 outbreak has prompted efforts to adopt ICT-enabled distance learning strategies to sustain teaching/learning [2]. A review of the latest improvements made to the 2015 revised national curriculum in South Korea shows that an emphasis is placed on the importance of students' computational thinking abilities [3]. The emphasis highlights the need to make the learning of computing skills more easily accessible in elementary school education. For example, the South Korean government has promoted ICT-enabled, textbook-less classes, incorporating computer program coding lessons in the regular curriculum to foster the fourth industrial revolution, and has facilitated educational innovation away from a focus on theory towards hands-on ICT practice sessions [1]. Despite this top-down guideline, some concerns have been reported that training in specialized computing skills could reduce students' motivation to learn, leading to a decrease in their concentration, possibly impacting the quality of classes [4]. It is notable that review of statistical materials relating to classroom-based teaching and learning in the past shows that approximately 35% of South Korean students reported that they enjoyed their classes—behind the corresponding responses from France (55%) and the U.K. (48%). The findings confirm that some measures are needed to foster student enthusiasm for classes and to enhance the level of their involvement during classes [3].

This article concerns the development of a blockchain education program utilizing gamification to encourage elementary student learners to develop an interest in blockchain, identifying implications for how to educate the founding principles of blockchain by analyzing keywords and topic modeling language networks. Sub-goals covered include the following:

(1) To develop an educational program on blockchain principles using gamification based on the six stages of the ASSURE model.
(2) To analyze focus group perspectives on the developed program for learning blockchain principles using language network approaches involving keyword centralities and topic modeling.

2. Related Research

2.1. Gamification as a Mechanism of Learning

The exploitation of gamification, where game-like elements are combined with conventional classroom approaches, is considered to be a positive way of encouraging students to more spontaneously take an interest and of helping them pay more attention to their classes. Gamification has the merits of offering students fun experiences induced by games while studying their subjects so that their learning experience becomes more enjoyable, and of providing tangible indicators that allow students to instantaneously check on their own achievements [5].

The term 'gamification' was coined from the word 'game' and was first used by Nick Pelling in 2002. Gamification means combining game-based mechanisms, aesthetic elements, ways of thinking, etc., in ways that encourage immersion, motivate student actions, facilitate learning, and help students to solve problems in non-game-like contexts [6]. In the foregoing, 'game' can be defined as an activity that includes skills, knowledge, and opportunities for solving problems under certain sets of rules and making efforts to win [7]. A game provides clear rules and purposes, clarifying the conditions for winning and terminating the game. It can provide users with a sense of purpose and help raise the level of interest in games.

A wide range of studies, both domestic and international, have been conducted to consider the incorporation of gamification into education so that the concentration skills of students can be improved. For example, Randel et al. [8] analyzed studies of gamification-combined education over 28 years and found that 12 out of 14 interventions involving language and mathematics education identified were effective. Iannotti [9] observed improvements in empathy skills and altruism in students with implementation of role-playing in classroom education. Sitzmann [10] analyzed education approaches in which 65 simulation games were implemented finding that, compared to their peers who received a more traditional education, students experiencing these showed learning benefits, i.e., an 11% increase in declarative knowledge, a 14% increase in procedural knowledge, and a 9% increase in knowledge-maintaining skills. More recently, studies of gamification have highlighted that the learning approach includes questioning, goal setting, decision making, and simulating, so that it possibly enhances learners' motivation, interest, participation, and comprehensive knowledge [1,11,12].

2.2. Blockchain Education

Since 2018 in South Korea, some universities have launched departments and training courses for blockchain. Table 1 below lists the department management details of each university. Overseas educational institutions are also conducting blockchain-related courses, including MIT, EU Business school, Fordham University, and Hochschule Mittweida University; the outline content of the educational programs conducted by each institution is shown in Table 1 [13]. Most schools have recently been running blockchain education courses. While some schools conduct programs centered on blockchain technology itself, others divide programs by subdividing blockchain technology, and some programs are grafted onto other fields of study. These other fields of study include economics and business—the fields are not diverse.

Table 1. Blockchain Programs Underway.

<table>
<tr><th colspan="4">Step</th><th colspan="4">Overseas</th></tr>
<tr><th>Institute</th><th>Program</th><th colspan="2">Main Courses</th><th>Institute</th><th>Program</th><th colspan="2">Main Courses</th></tr>
<tr><td>Kukmin University</td><td>Blockchain technology</td><td colspan="2">· Blockchain platform
· Blockchain dAPP development
· Blockchain token economy
· Blockchain and media</td><td>MIT</td><td>Blockchain technology: Business innovation and application</td><td colspan="2">· An introduction to blockchain technology
· Bitcoin and the curse of the double-spending problem
· Costless verification: blockchain technology and the last mile problem
· Bootstrapping network effects through blockchain technology and cryptoeconomics</td></tr>
<tr><td>Dongguk University</td><td>Blockchain</td><td colspan="2">· Cryptoblockchain
· Consensus algorithm
· Advanced cryptography
· Bitcoin and cryptocurrency
· Public blockchain</td><td>EU Business School</td><td>Blockchain management</td><td colspan="2">· Blockchain basics
· Cryptocurrencies and fintech
· Blockchain applications and new business models
· Blockchain and sustainable development</td></tr>
<tr><td rowspan="2">Sogang University</td><td rowspan="2">Blockchain</td><td>Block-chain System</td><td>· Introduction to blockchain and distributed ledger
· Applications of blockchain technology
· Blockchain service modeling</td><td rowspan="2">Fordham University</td><td rowspan="2">MBA</td><td>FinTech</td><td>· Fintech—an introduction
· System analysis and design
· Data mining for business
· Text analytics</td></tr>
<tr><td>Block-chain System</td><td>· Applications of blockchain technology
· Financial markets under IT environments
· FinTech platforms</td><td>Blockchain secondary</td><td>· Blockchain
· Digital currencies
· Blockchain tech and app development
· Blockchain: industry disruptor and creator</td></tr>
<tr><td>Hanyang University</td><td>Blockchain and crypto-currency</td><td colspan="2">· System software
· Secure coding
· Blockchain and information security
· Smart contract and dAPP</td><td>Hochschule Mittweida University</td><td>Blockchain and distributed ledger technology (DLT)</td><td colspan="2">· Blockchain technical applications
· Blockchain non-technical applications</td></tr>
</table>

As illustrated above, blockchain education programs primarily target adults or talented blockchain students whether in South Korea or elsewhere around the world, but there are also blockchain education programs targeting younger population segments. A university in South Korea introduced an effective educational tool that easily teaches blockchain to students 16 years of age or older, a teaching and learning method that utilizes a technical play called 'Village Coin' and a boardgame [14]. The play consists of four acts—its contents deal with the value of money, the issue of exchange of money and goods, currency evaporation, security and trust in the local currency, and the blockchain. In addition, the Village Coin board game was designed to convey how to replace the financial elements of banking, real estate ownership, and currency with blockchain technology, which was developed based on the Monopoly game. The education model, which combines play and board games, was found to be suitable for conveying complex technical ideas to students. Games represent a convenient tool for in-depth education of cryptography and blockchain theory. In an example of research on use of this educational model to teach blockchain technology to elementary school students, card games and worksheets were used to help students understand the core principles of preventing forgery and alteration of the blockchain [15].

The card game allowed all participants to obtain a total sum for two words selected by the learner, and if the words gave the same sum, the learner obtained a score so that the learner could learn the principle of the hash of the blockchain. Game players could learn the distributed record ledger by writing down the sum of the obtained scores in their respective worksheets. Thus, gamification is a tool that can be used for teaching blockchain technology to students in elementary, middle, and high schools [14,15], and many educators use games to teach complex and challenging skills to young learners [8]. Boardgames were developed in some cases to teach blockchain mechanisms, public blockchain, and private blockchain to children [16]. The boardgame developers thought that blockchain education targeting children or teenagers needed to focus on helping them understand blockchain principles using metaphor rather than through in-depth use of the technology [16]. Accordingly, conceptual principles or types of blockchain were incorporated into the educational contents and the education programs were designed to utilize a variety of media, including educational skits, learning games, cartoons, video clips, etc., to encourage students to self-direct in learning and develop an interest in the learning content.

2.3. Instructional Design Using ASSURE Model

The ASSURE (Analyze learners-State objectives-Select methods, media, and materials-Utilize media and materials-Require learner participation-Evaluate and revise) model proposed by Heinich et al. [17] refers to an education system or set of guidelines that can be used by teachers in developing teaching plans that use digital technologies [18]. The model is a teaching model that specifies how instructors can appropriately use a variety of media while delivering a lecture. In particular, the model regards educational media, teaching aids, and lesson materials as critical to the level and quality of teaching content. Furthermore, the model emphasizes how to utilize digital technology-enabled teaching media in the ADDIE (Analysis-Design-Develop-Implement-Evaluate) model, frequently used as a teaching design model to enable learners to be more focused. Therefore, the model is deemed appropriate for utilizing online tools to provide contextualized education in on and offline classrooms in accordance with the changes in classroom environments in the wake of the COVID-19 pandemic.

The six steps, questions, and strategies for designing lessons in accordance with the ASSURE Model are described in Table 2 [19].

In Step 1, demographics, general characteristics, learning style, and entry competencies of learners are analyzed. In Step 2, objectives of lessons to be developed are stated; learning outcomes to be achieved by fulfilling the objectives can be assessed, which can be conducive to providing and configuring a learning environment. Mager's [20] principles for stating the objectives can be used to guide the formulation of lesson objectives, focusing on learners and suggesting behavioral targets for them in order to design a learner-directed lesson. The principles imply that it is necessary to suggest conditions in which observable behaviors are triggered and specify standards by which the fulfillment of lesson objectives can be assessed [19]. In Step 3, teaching methods, media, and/or materials are selected. In this step, existing materials can be analyzed to plan and configure methods, media, and materials suitable for the education program to be designed. Instructors must consider lesson formats and methods that can contribute to learner outcomes and the fulfillment of specified teaching objectives. Elements of new material design review include objectives, targeted audience, costs, facilities, time, etc. In Step 4, the media and materials specified in Step 3 are reviewed for their on-site applicability. The contents of teaching materials are assessed to see if they can contribute to fulfilling instructional objectives. In addition, the elements of contents that instructors need to be aware of before the contents are applied directly on educational sites are reviewed, if any. In Step 5, how to engage learners in classes is discussed. A wide range of teaching techniques is considered before a technique that can ensure an optimized teaching effect is specified. As learners are encouraged to engage in classes, they will be more focused and stand a better chance of understanding lessons. In the final step, the developed teaching program is assessed. By this step, the teaching model can be finally refined and supplemented to deliver a more complete education program. Educational programs are primarily assessed as they are applied to learners or instructors on a pilot basis and their effectiveness analyzed. Such an effectiveness analysis can identify improvement opportunities in applicable education programs and competencies to which the programs are directly beneficial.

Table 2. 6 Steps of the ASSURE Model.

Area	Question	Strategy
Analyze learners	Who would be the audience?	· Demographics: pedagogy and andragogy · General characteristics · Entry competencies · Learning styles
State objectives	What would students need to learn?	· Learning outcome assessment · A-B-C-D Principles · Audience, behavior, condition, degree
Select methods, media, or materials	What should instructors use for face-to-face, hybrid and online teaching?	· Select instructional materials · Produce new materials · Repurpose existing materials
Utilize media and materials	How would instructors use the materials?	· Preview materials · Prepare environment · Provide instruction
Require learner participation	Would students actively engage in classes?	· Discussion · Small group activities · Educational game · Feedback · Formative assessment
Evaluate and revise	How can education be supplemented?	· Program advancement · Effectiveness analysis

A host of education programs based on the ASSURE model have been developed. Karakis et al. [20] designed a mathematical lesson on fractional numbers, utilizing computer-aided media in accordance with the teaching design principles of the ASSURE model. They improved the proficiency of students with their lessons and emphasized that the educational materials and activities developed in the lesson had positive impacts on the attitude of students toward computer-aided lessons. Mehmet [21] planned an English language instruction on the basis of the ASSURE model. As the planned education program was applied to students, most of them enjoyed the activities and materials provided in the program, and successfully performed the exercises provided in class [18]. As such, the ASSURE model is frequently used in education research designs for a variety of applications utilizing digital media, delivering educational effects.

3. Methodology

The purpose of this research was to teach blockchain at the children's level to enable students to understand the conceptual principles underpinning blockchain and, ultimately, to develop an interest in it. To fulfill this purpose, we decided to develop an education program. To develop the education program, teaching design models were first analyzed, and the ASSURE model emphasizing the utilization of digital media was selected among the existing teaching design models as the development model for the education program, as opposed to the more popularized ADDIE model [17]. Then, the education program was designed in accordance with the six steps in the ASSURE model (Figure 1).

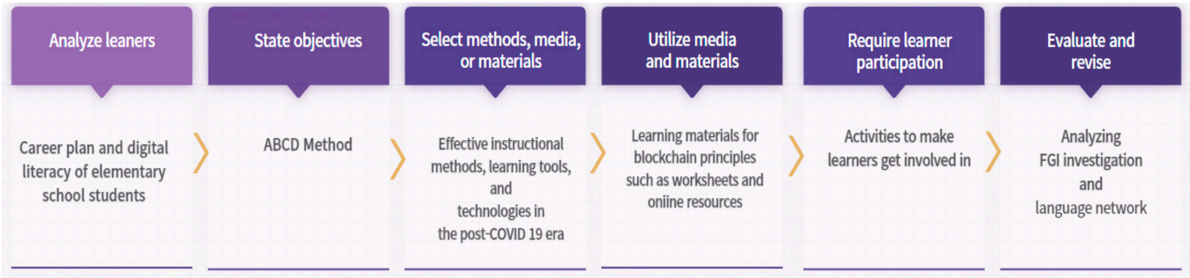

Figure 1. 6 Stages of Developing the Blockchain Education Program in this Article.

First of all, in the 'Analyze Learners' step, the audience targeted by the education program was selected by analyzing the findings from the 2018–2020 survey on desired jobs and digital literacy of South Korean elementary school students [22–25]. Secondly, in the 'State Objectives' step, the purpose of the education program was clearly specified. The objectives were stated in detail in accordance with Mager's [19] objective statement principle of the 'Audience, Behavior, Condition, Degree (ABCD)' method. Education experts and blockchain technology specialists collaborated in specifying the instructional objectives. Thirdly, to select teaching methods and media, blockchain education methods and tools, media, and materials, etc., used in designing education programs recently after the COVID-19 outbreak, were analyzed. To develop teaching methods and materials, we studied references in the study literature to identify and organize techniques and materials used in blockchain education programs. The studies covered in the literature review included educational development research on blockchain education, targeting not only elementary students, but also graduate students of business schools or adults. As the studies covering blockchain teaching methods for elementary students were too few, it was hard to restrict the studies. Accordingly, we expanded the scope of the targeted audience. We analyzed a total of six studies: three targeting elementary students, two covering undergraduate students, and one for adults familiar with java technology [16,26–29]. The analysis findings were used as inputs for selecting teaching methods and the media to be developed and utilized. Fourthly, the teaching methods and media selected in Step 3 were used to develop worksheets and instructional materials to be used in the education program proposed. The content of the education program was quantitatively verified for validity by a panel of ten blockchain technology and pedagogy experts, including one professor of elementary school computer education, two doctoral students of computer education, and six blockchain technology researchers, and their feedback regarding the appropriateness of the designed education contents was gathered. A CVR value was calculated by applying the content validity ratio (CVR) equation for the quantification study of Lawshe [30] extensively used in social science studies. The mathematical formula for the above is as shown in Equation (1), where N is the total number of the assessors and n_e is the number of assessors who responded that it is adequate.

$$Content\ Validity\ Ratio = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} \tag{1}$$

According to Lawshe's [30] study, the minimum CVR is 0.62 when the number of assessors is 10. Therefore, the educational contents were deemed to be viable in this research when the CVR value was at or above 0.62. For the standards for developing instructional aids, the standards and questions concerning considerations for instructional aid selection in Shim et al.'s [31] study were referenced. They claimed that instructional aids must be safe, appropriate, durable, and cost-effective from functional perspectives. Accordingly, the instructional aids, including cards, boards, and ledgers developed in this research, were put to viability review from all those four perspectives. In Step 5, how to encourage learners to engage in the program was specified. It is necessary to motivate learners to actively engage in learning. Accordingly, in this study, motivation techniques primarily used in educational program design were retrieved from the existing literature and an appropriate strategy to motivate learners to engage in the program was determined. Lastly, in the 'Evaluate and Revise' step, the learning games and education program based on such games were designed and evaluated with reference to the elements specified and designed from Steps 1 to 5. The education program was refined and rendered more complete as informed by the evaluation findings. To evaluate the education program, focus group interviews (FGIs) were conducted. The FGIs were conducted with the ten experts who participated in the validity assessment in Step 4 of the ASSURE model and their expert feedback on the strengths and weaknesses of the education program was gathered. The interview findings were converted to text by an AI-enabled language processing application, and keywords were retrieved from the gathered data using the social network analysis software NetMiner 4.3 program, and topic modeling analysis based on latent Dirichlet allocation (LDA) was conducted. Keywords in unstructured data of text format were extracted and converted to structured data, and networks were generated from the extracted keywords and rendered into visualized representations.

4. Results

4.1. Blockchain Education Program Targeting Elementary Students Based on ASSURE Model

4.1.1. Analyze Learners

The purpose of this process was to provide a basis for facilitation of a comprehensive comparison of the prospective jobs desired by elementary school students in South Korea. This job comparison was intended to assess how much the learners were interested in jobs related to the cutting-edge technologies of the future. According to a survey conducted by the South Korean Ministry of Education for three years from 2018 to 2019 and 2020 on 23,223 students of 1200 schools across South Korea, including 6352 in elementary schools, 8339 in middle schools, and 8532 in high schools, the students desired a variety of jobs, but revealed a similar pattern [22]. Regardless of their school grades, all students were found to favor roles as athletes and teachers the most. What was noteworthy was the rank of computer scientists or software developers related to blockchain; when the top ten desired jobs per school grade were compared, elementary school students did not desire jobs related to cutting-edge technologies. Those jobs ranked 10th in 2018, and 9th in 2019. They did not appear in the top ten jobs in 2020. Among high school students, computer-related jobs were ranked at higher places than among middle school students. They ranked 8th in 2018, 4th in 2019, and 7th in 2020. By this comparison, we can see that preference for jobs utilizing cutting-edge technologies of the future, such as computer or blockchain technology, lower among the elementary school students than among the middle school and high school students. A comparison of desired jobs per year is shown in Table 3.

Digital literacy means certain competencies for understanding and utilizing digital technologies [32]. This encompasses, beyond simple familiarity with computers, competencies for communication enabled by digital technology or devices, adaptability to the digital environment, or combinations of such qualities. Blockchain is also empowered by digital technologies, and the level of digital literacy may suggest how amenable the learner is toward blockchain concepts and how a blockchain education program should be designed. The digital literacy survey of South Korean elementary school students, covering 11,055 learners in 2018, 8847 in 2019, and 9611 in 2020, was reviewed. Table 4 shows the means and standard deviations of digital literacy per element [23–26].

Table 3. Comparison of Jobs Desired by Elementary Students in South Korea across 2018, 2019, and 2020 [22].

		2018 (N = 6352)	2019 (N = 8339)	2020 (N = 8532)
Elementary students	1	Athlete	Athlete	Athlete
	2	Teacher	Teacher	Doctor
	3	Doctor	Creator	Teacher
	4	Cook	Doctor	Creator
	5	Creator	Cook	Professional gamer
	6	Police officer	Professional gamer	Police officer
	7	Legal expert	Police officer	Cook
	8	Singer	Legal expert	Singer
	9	Professional gamer	Singer	Cartoonist (webtoon writer)
	10	Baker	Beauty designer	Baker
	No. (%)	7680 (50.5)	6505 (51.3)	5101 (48.8)

Table 4. Digital Literacy Trends of South Korean Elementary Students across 2018, 2019, and 2020. (Score Min. = 0, Max. = 4).

		2018 (N = 11,055)		2019 (N = 8847)		2020 (N = 9611)	
		M	SD	M	SD	M	SD
ICT	Search information	2.66	1.09	2.45	1.13	2.47	1.22
	Analyze and evaluate information	2.90	1.10	2.81	1.18	2.81	1.22
	Organize and create information	1.89	1.19	2.13	1.28	2.15	1.28
	Utilize and manage information	2.80	1.21	2.70	1.31	2.68	1.38
	Communicate information	2.65	1.01	2.32	1.02	2.39	1.07
CT	Abstraction	2.41	1.15	2.21	1.06	2.50	1.41
	Automation	1.92	1.30	1.77	1.31	1.72	1.37
Grand total of means		17.23	5.96	16.39	6.27	16.71	7.14

According to the survey, when the digital literacy scores in all areas were summarized, the mean and standard deviation were the highest in 2018 at 17.23 and 5.96 respectively, and the lowest in 2019 at 16.39 and 6.27, respectively. Among the ICT elements, the 'Organize and Create Information' posted the lowest means with consistency, with the mean and standard deviation at 1.89 and 1.19 in 2018, 2.13 and 1.28 in 2019, and 2.15 and 1.28 in 2020, respectively. Among the CT elements, the mean scores for 'Automation' were all found to be low when compared with 'Abstraction', with the mean and standard deviation at 1.92 and 1.30 in 2018, 1.77 and 1.31 in 2019, and 1.72 and 1.37 in 2020, respectively. These statistics suggest that in terms of digital literacy, South Korean elementary school students found it relatively challenging to gather data or convert it into a different format to solve problems. In addition, it was confirmed that it was difficult for them to design and implement a program according to the algorithm. Therefore, we infer that when we develop an education program, it is important to provide an experience where students can solve problems or organize/create information using blockchains.

4.1.2. State Objectives

When designing the education program, we intended, firstly, to promote understanding of and interest in blockchain among the elementary students, and to foster talent for a sustainable future with quality education programs. To specifically state the objectives, we used the audience, behavior, condition, degree (ABCD) method, the objective statement of the Mager principles [19]. Figure 2 details the educational objectives specified in accordance with Mager's [19] objective statement principles applied to this education program.

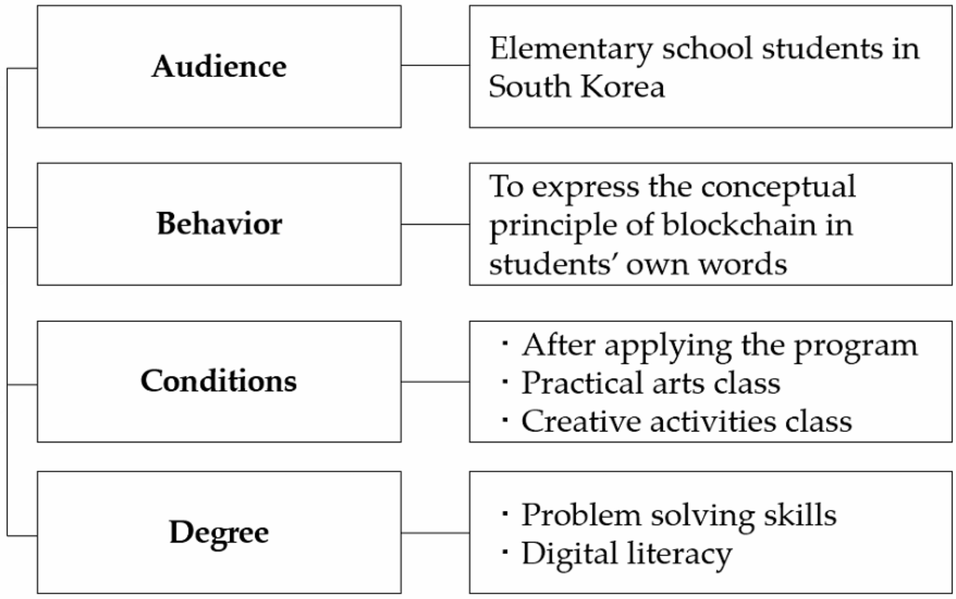

Figure 2. Instructional Objectives.

Firstly, in terms of audience, it is emphasized that it is important for instruction design to focus on what is done by learners rather than by instructors. To configure a lesson systematically, it needs to be recognized that the fulfillment of an objective is determined by what is performed by whom. Specifying an instructional objective starts from the statement of what is converted by whom. In Step 1 of the ASSURE model, 'Analyze Learners', it was found that the South Korean elementary school students did not prefer jobs requiring digital technologies and strong computing competency, and faced difficulties with information-enabled problem-solving skills or creation/implementation of information. Therefore, elementary school learners in South Korea were defined as the audience for the education program proposed. Secondly, in terms of 'Behavior', competency or behavior to be attained by learners through education is specified. As this education program was intended to foster understanding of and interest in blockchain among elementary students, it needed to be determined whether learners could understand and act on the consensus mechanism of blockchain and conceptual principles of blockchain types among various concepts related to blockchain. Actions expected after the application of this education program are that the learners can express the foundational concepts and principles of blockchain in their own language. Thirdly, 'Condition' means circumstances or conditions in which a learner's behavior can be manifested. We would like our education program to enable learners to understand blockchain better. Furthermore, we expect the program to be effective in helping elementary school students learn concepts related to cutting-edge technologies in practical art classes and innovation classes of creative activities programs. Fourthly, 'Degree' is intended to provide for benchmarks assessing the fulfillment of objectives. We did not restrict the learning performance assessment standards to the understanding of blockchain concepts but to the improvement of problem-solving skills and digital literacy enabled by blockchain. We designed the education program to encourage learners to develop an interest in blockchain and to be inclined to learn and study the subject with a stronger commitment, by experiencing and understanding the principles of blockchain. After all, what matters in fostering talents from the perspective of sustainable development education is not just knowledge about blockchain but also understanding of and insight into blockchain.

Thus, the educational program described in this paper allows elementary school learners to handle various areas of knowledge and information that can reasonably solve problems to cultivate the creative convergence talents required by future societies. It can also contribute to fostering elementary school learners' ability to handle interdisciplinary fields of knowledge and information so that they can reasonably solve problems and cultivate creative convergence talents required by future societies. Specifically, we intended to convey understanding of blockchain principles, a key technology in the fourth industrial revolution, and to remove psychological fear about blockchain to provide a foothold to enable students to grow into experts.

4.1.3. Select Method, Media, or Materials

In this step, instructional methods and media or materials required for lessons were selected. Table 5 shows analysis findings on the instructional methods and tools for teaching blockchain identified in previous studies.

Table 5. Previous Studies on Instructional Methods and Tools for Teaching Blockchain.

Author (Year)	Audience	Instructional Methods	Tools	Findings
Xing [26]	Students in blockchain courses	· Lecture · Experimental learning · Gamification · Simulations	Software tool	The small Java graphical user interface application named ChainTutor can be possibly used in classroom teaching or self-learning of blockchain concepts
Kim & Park [16]	Elementary students	· Lecture · Experimental learning · Gamification · Problem-based learning · Simulations	· Unplugged worksheet · Boardgame materials	The intervention strengthened learners' capacity for information processing, communication, and community spirit
Jung et al. [15]	Elementary students	· Lecture · Experimental learning · Gamification · Problem-based learning · Simulations	· Unplugged worksheet · Boar game materials	They proposed a method to prevent the forgery and falsification of the blockchain.
Choi & Koo [27]	Elementary students	· Lecture · Experimental learning · Gamification · Problem-based learning · Simulations	Unplugged worksheet	A blockchain unplugged program positively affected elementary school learners in terms of learning interest, difficulty, and understanding

Table 5. *Cont.*

Author (Year)	Audience	Instructional Methods	Tools	Findings
Dettling & Bettina [28]	Business or business information technology students at Bachelor's and Master's level	· Experimental learning · Gamification · Problem-based learning · Simulations	Software tool	A software tool Bloxxgame supports experience-based instruction of blockchain concepts and can be used in class or for online teaching.
Kaden et al. [29]	Accounting students in college	· Lecture · Experimental learning · Problem-based learning · Simulations	· Textbook · Software tool	Using code-based methods to teach blockchain to accountants was feasible and instructive.

In terms of instructional methods for blockchain, experimental learning and simulation were included in all the six studies. In addition, gamification, problem-based learning, and lecture were used in five of them. Discussion was used in none of the studies. This indicates that experiments or games are included in programs targeting both children and adults, unless the programs are intended to cover blockchain technology in-depth, and that the programs are designed to deliver problem-based learning beyond the understanding of blockchain concepts, so that the learners can solve problems encountered in daily life. In addition, expert lectures were included to assist with the understanding of concepts rather than simple experiments.

In terms of educational tools, including blockchain education media and materials, unplugged worksheets were included in all programs targeting elementary students. Blockchain education programs targeting adults used software programs, such as java applications or R-based coding programs, or bespoke online software. Some lessons used instructional materials designed for undergraduate classes, not just for blockchain education. None of the six studies used online video clips in classes. The use of unplugged worksheets in all programs targeting elementary students seems to have factored in the level of elementary school learners or lack of digital infrastructure in schools. However, as online classes are extensively used in the wake of the COVID-19 pandemic, the development of worksheets utilizing online tools may be required.

Therefore, this study used an instructional method containing games accompanying experiments. In addition, the instructor's lectures and briefings were added as precursors to instructional games to improve the understanding of students. Furthermore, online tool-based worksheets were developed in addition to unplugged worksheets compatible with conventional classroom environment to ensure continuity of lessons in an online environment in the event that tele-learning classes were needed at short notice.

4.1.4. Utilize Media and Materials

Design Educational Contents

In Step 3, we selected instructional methods and tools. Educational content was configured based upon the selection, and instructional materials were developed to enable systematic instruction. Standards for educational content required to be included in the lectures of instructors to help with the understanding of learners were established. It was necessary to configure the educational content to help learners develop basic knowledge without encompassing an excessively broad scope, and in-depth details of the level of learners was applied. Given that blockchain lessons are not included in the current educational curriculum of South Korea and therefore it is hard for teachers to allocate a significant amount of time, the blockchain education program was designed to consist of two or three lessons, so that it could be readily deployed on-site. We designed the educational contents with reference to the blockchain education programs analyzed in Step 3, primarily drawing upon Kim and Park's [16] educational contents. They dealt with the basic concepts and types of blockchain in their educational content. Jung et al.'s [15] study focused on the tamper-proofing mechanism of blockchain and proposed an education program focused on the mechanism. Choi and Koo's [27] study dealt with the concepts and formation process of blockchain, distributed storing of blockchain, encryption and validation of blockchain, the connection of blockchains, and cases of blockchain utilization, designing educational content consisting of six lessons. These two studies were referenced in terms of instructional method and material development.

Lesson 1 of the designed educational contents dealt with the basic concepts of blockchain, with lessons 2 and 3 covering the types of blockchain. The basic concepts of blockchain in lesson 1 included the features of blockchain, the principle of distributed storing, consensus mechanism, and the basic concept of cryptocurrency. Lesson 2 focused on public blockchains, covering their features, principles, strengths, and weaknesses, and utilization cases. Lesson 3 dealt with private blockchains, describing their features, principles, strengths and weaknesses, and utilization cases. The developed educational contents were deemed to be viable by all panel members, with a minimum CVR value of 0.78. Details of the findings are shown in Table 6. Therefore, the educational contents of the education program developed were deemed to be viable.

Table 6. Contents of Blockchain Education and Validity.

Periods	Topic		Contents	CVR
1	Basic concepts of blockchain		· Features of blockchain · Principle of distributed storing · Consensus mechanism · Basic concepts of cryptocurrency	0.78
2	Blockchain types	Public blockchain	· Features of public blockchain · Principle of public blockchain · Strengths and weaknesses · Utilization cases	0.89
3		Private blockchain	· Features of private blockchain · Principle of private blockchain · Strengths and weaknesses · Utilization cases	0.89

As per the designed educational contents, we developed lesson-specific worksheets, including worksheets usable in on and offline environments. Figure 3 shows unplugged worksheets usable in offline classes and online worksheets that can be used when remote lessons are adopted in place of offline classes.

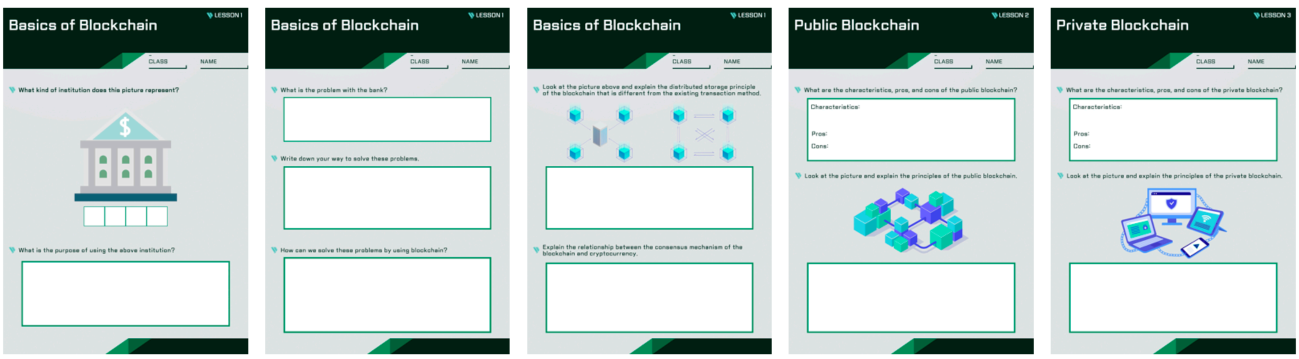

Figure 3. Unplugged and/or online interactive worksheets.

The worksheets were designed to ask open-type questions by which teachers could check and revisit content learned in classes while delivering a lecture. In addition, the same worksheets were adapted to online interactive worksheets on the Liveworksheets platform. Blank boxes were included in the online worksheets to allow students to freely state their comments, and teachers were permitted to evaluate and provide feedback on the worksheets completed by students on the online platform.

Design Educational Games and Tools

After lesson-specific educational content was designed, corresponding educational games and tools were developed. Three educational games were developed to help the students understand the consensus mechanism and foundational principles of public and private blockchains among the concepts of blockchain. The blockchain educational games proposed in this paper were produced based on vital elements of a well-designed educational game according to Shute and Ke [33]. Elements proposed by them are specific objectives/rules, interactive problem solving, adaptive challenge, ongoing feedback, uncertainty, control, and sensory stimuli. The educational games proposed were described per game element as shown in Appendix A.

The first educational game is a learning game designed to help with the understanding of consensus mechanism which is one of the foundational concepts of blockchain. In the first step, teams of two players are organized and a set of cards is given to each party. The team members place six white cards face down. Each team member shouts one of the cryptocurrency symbols and turns around each card of the opponent team at the same time. If the cryptocurrency symbol of the turned card matches the symbol shouted, the applicable player can take the card of the opponent team. When all white cards placed are used up, the game is played with blue cards. The basic rules are the same, but two cryptocurrency symbols must be shouted and two cards of the opponent team turned around this time. If both symbols are matched, two cards of the opponent team can be taken. Lastly, when it comes to red cards, three red cards of the opponent team can be taken only when three cryptocurrency symbols are matched. A player who has won two out of three rounds is the final winner. Figure 4 shows an example of instructional tools developed for the educational game.

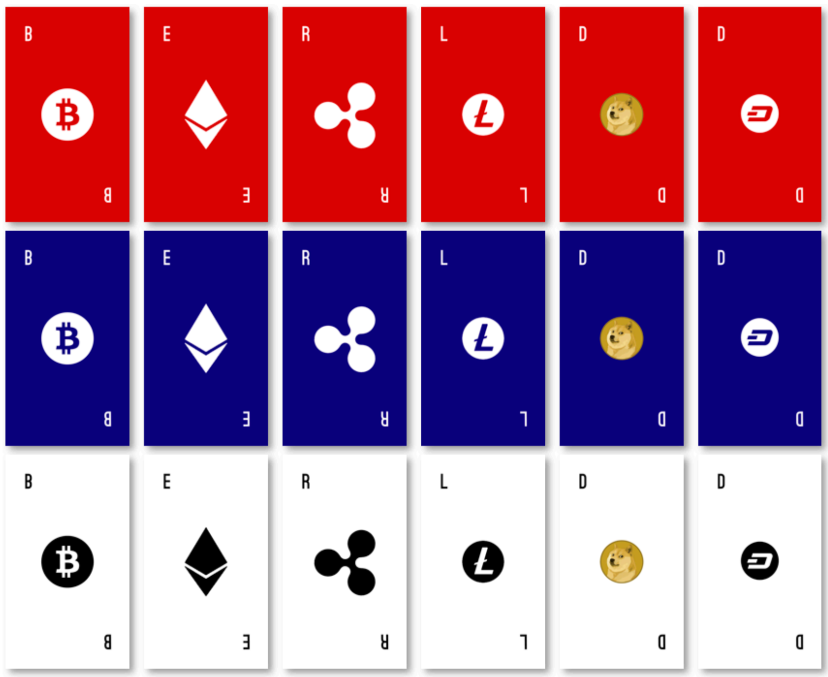

Figure 4. Card Samples for Blockchain Consensus Mechanism Game.

The second educational game designed was used in Lesson 2 to help the students understand the principle of a public blockchain. Each student starts with 50 coins. When the game is ready, every student chooses the color they want on the board. Students place their markers on the board in the color they choose. Students decide the order of the games by rock-paper-scissors. When the game starts, a player throws the dice in front of all players. Every student records every transaction on the ledger every time he/she throws the dice. The player throws the dice and moves the marker forward when the number comes out. He/she can throw the dice once more if the destination's color is the same as the color of his/her choice. Double trading is possible in the next transaction. If the number of dice is odd, the player should pay coins to the other party, and if the number is even, he/she can take the other's coins. The last remaining person will be the winner, or the person who has obtained the most coins in a set time will be the winner. If the player does not have coins, he/she can sell his/her slot to the other party, and the price is ten coins. It is important to note that all of these transactions must be recorded in their ledgers by all students.

The last learning game is intended to help with the understanding of the principle of private blockchain. Unlike a public blockchain, when teachers and students play a private blockchain game, they need to select students who play designated intermediaries. During this process, students can naturally feel the difference depending on the type of blockchain. It is also understandable that the concept of decentralization or transaction transparency can be blurred in private blockchains since game participants give records of transactions to intermediaries. Figure 5 shows a sample of teaching aids for public and private blockchains.

LEDGER

Name	1	2	3	4	5	6	7	8	9	10	No. of Coins
Andy											
Blair											

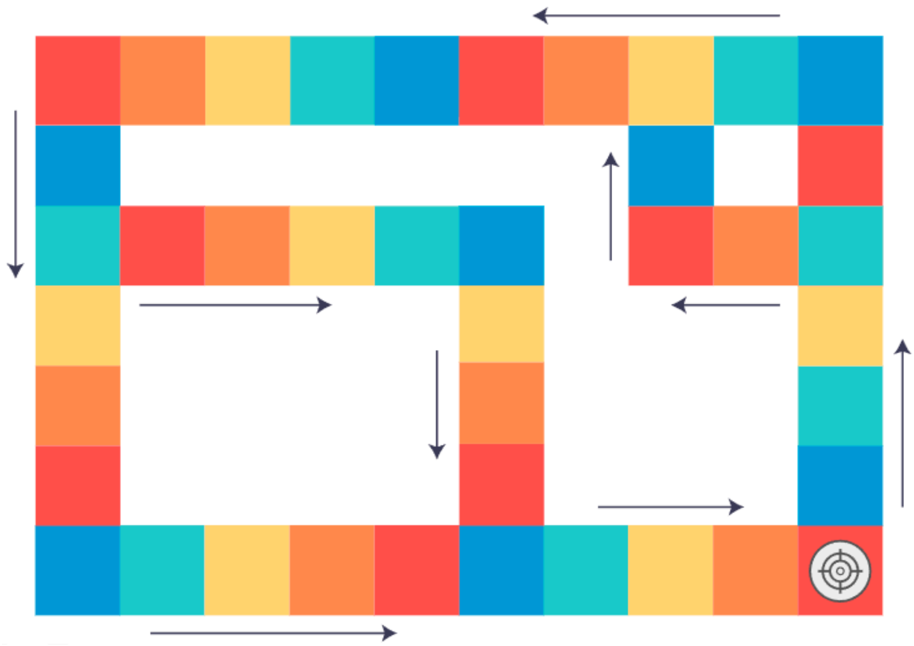

Figure 5. Teaching Aids for Public and Private Blockchain Game.

The validity of the teaching aids was verified to assess whether the learning games developed were applicable on education sites. The same experts who participated in the validation of the educational contents took part in the teaching aid verification. Validity assessment outcomes of the teaching aids and contents developed are as shown in Table 7. In the assessment, CVR values were at or above 0.62 for all items, indicating that the cards, boards, and ledgers were safe and suitable for education in all respects. In particular, in terms of economic efficiency, CVR values were the highest with CVR = 0.94 for cards, CVR = 0.95 for boards, and CVR = 0.96 for ledgers. This indicated that the teaching aids were sufficiently usable even in a poorly equipped classroom environment. With respect to durability, the teaching aids were found to be viable, but CVR values were somewhat lower than for other items, with CVR = 0.69 for cards, CVR = 0.75 for boards, and CVR = 0.72 for ledgers. Therefore, it was inferred that the developed aids need to be made of more sturdy materials.

Table 7. Validity of Blockchain Education Aids and Contents.

Teaching Aid	Standard	CVR
Card	Safety	0.89
	Suitability	0.78
	Durability	0.69
	Economic efficiency	0.94
Board	Safety	0.92
	Suitability	0.84
	Durability	0.75
	Economic efficiency	0.95
Ledger	Safety	0.95
	Suitability	0.89
	Durability	0.72
	Economic efficiency	0.96

4.1.5. Requires Learner's Participation

Step 5 of the ASSURE model is about developing a method to motivate learners to engage in games. It is important to design elements of motivation properly to enable learners to actively participate in classes. All the previous blockchain education studies referenced in Step 3 included elements of competition to motivate learners to engage in class. However, Dettling and Bettina's [28] study offered coins as rewards and used Applaying to further boost the attention level of students. Jung et al.'s [15] study offered certification for each objective to be fulfilled. Rewards in games play a critical role in encouraging the engagement of learners. Accordingly, the education program developed offered coins to winners to encourage the learners to participate more actively in games. These rewards can add more dynamism to learning games and allow students to feel as if they were trading cryptocurrencies in reality.

4.2. Evaluating the Contents of the Program through Language Network Analysis

4.2.1. Analyze Keywords

As for basic analysis, to retrieve keywords, morphemes were extracted, and word classes were identified using the NetMiner 4.3 Program. In the experts' analysis, 40 nouns were found among the words indicating strengths and 38 nouns among the words indicating weaknesses. A user dictionary was then used in data preprocessing to identify keywords. After data preprocessing, 37 keywords denoting strengths were found and

37 keywords indicating weaknesses. The occurrence frequencies of the collected keywords were analyzed (Figure 6).

Figure 6. Word Clouds of Program Strengths and Weaknesses.

In the analysis, for the strengths, occurrence frequency was in the order of student (8.0), learning games (6.0), blockchain (6.0), school (5.0), and worksheet (4.0). This indicates that most of the students were satisfied with the blockchain education method using worksheets and learning games in class. In contrast, for weaknesses, occurrence frequency was in the order of student (11.0), learning games (7.0), blockchain (7.0), school (4.0), education (4.0), and level (2.0), which suggests that some students wanted difficulty level to be added to the blockchain learning game used in class. Table 8 shows the analysis outcomes of degree, eigenvector, and betweenness centralities for keywords in the strengths and weaknesses identified in expert interviews.

Table 8. Centrality Analysis of Program Strengths and Weaknesses.

Strengths				Weaknesses			
Keyword	Centrality			Keyword	Centrality		
	Degree	Eigenvector	Betweenness		Degree	Eigenvector	Betweenness
blockchain	0.25	0.56	0.27	difficulty	1.00	0.15	0.04
education	0.22	0.51	0.08	student	1.00	0.50	0.04
learning games	0.22	0.34	0.19	blockchain	0.97	0.29	0.04
school	0.22	0.28	0.21	education	0.97	0.18	0.04
research	0.19	0.00	0.02	learning games	0.97	0.29	0.04
student	0.16	0.13	0.11	school	0.97	0.18	0.04
worksheet	0.12	0.11	0.10	fact	0.88	0.13	0.04
amount	0.09	0.13	0.09	level	0.88	0.13	0.04
element	0.09	0.09	0.01	principle	0.88	0.13	0.04
fun	0.09	0.09	0.01	research	0.88	0.13	0.04
literature	0.09	0.00	0.00	understanding	0.88	0.13	0.04
lot	0.09	0.00	0.00	bitcoin	0.30	0.12	0.00

In the degree centrality analysis associated with the strengths of the program, degree centrality was found to be 0.25 or under for each word. Eigenvector centrality was rated to be 0.3 or higher for 'blockchain', 'education', and 'learning games'. In the betweenness centrality analysis, 'blockchain' and 'school' showed a betweenness centrality of 0.2 or higher. In contrast, in the degree centrality analysis associated with the weaknesses of the program, 'difficulty', 'student', 'blockchain', 'education', 'learning games', and 'school' showed higher degree centrality values of 0.97 or more, whereas the eigenvector centrality was 0.29 or higher for 'student', 'blockchain', and 'learning games'. These analysis outcomes suggest that associated words are used frequently in school classes to describe the strength of the program designed to teach the principles of blockchain and indicate that, to address the weaknesses of the program, learners need to be supported in connection with their challenges or in-depth activities prepared, depending on the varying level of learners.

4.2.2. Topic Modeling Analysis

To retrieve topics out of experts' unstructured feedback, LDA-based topic modeling was conducted. To filter words, the TF-IDF threshold was set to 0.5 and word length to 2 in a bid to eliminate frequently used words and words composed of two or fewer letters. Figure 7 shows the 2-mode spring visualization of the relations among top keywords consisting of each topic for strengths and weaknesses. The left is the topic modeling visualization of the strengths and the right is the topic modeling visualization of the weaknesses.

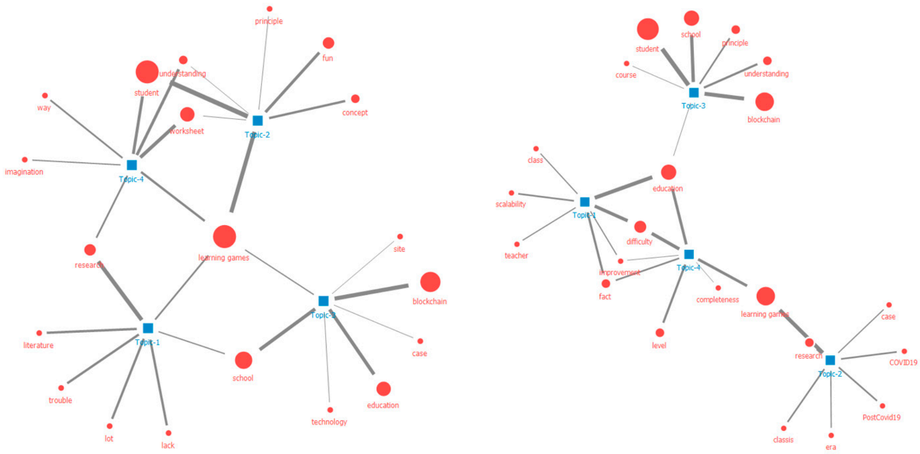

Figure 7. Topic Modeling Visualizations of the Strengths and Weaknesses.

In the topic modeling analysis of the strengths, four topics were extracted in the end, all with high relevance to 'learning games'. As for each topic, Topic-1 consisted of such words as 'research', 'school', 'literature', 'trouble', etc., with 'learning games' in the center. Based on these findings, Topic-1 suggests that the learning games were well designed, even though not many previous studies for learning games played in school were available. Topic-2 consists of 'learning games', 'students', 'worksheet', 'understanding', and 'fun', etc. To sum up, these topics indicated that the learning games and worksheets were configured to be interesting to and readily comprehensible by students. Topic-3 includes 'learning games', 'blockchain', 'education', 'school', 'case', and 'site', which suggests that the experts believe that the blockchain education program using learning games is suitable for deployment in school sites. Lastly, Topic-4 consists of 'learning games', 'students', 'worksheets', 'imagination', and 'way'. This indicates that the use of learning games and worksheets is effective in stimulating the imagination of students.

In the topic modeling of weaknesses, four topics were finally extracted. Unlike the strengths, several words were evenly distributed for the weaknesses rather than one dominant word. Firstly, Topic-1 comprised 'education', 'difficulty', 'scalability', 'class', and 'improvement', which indicates that the developed education program needs to be improved in terms of extensibility if it is to be used in classes. Topic-2 contained 're-search, 'learning games', 'COVID19′, 'Post-COVID19′, and 'research'. Words related to COVID-19 appeared in this topic, indicating that studies utilizing learning games are ever more required in the post-COVID 19-era. Topic-3 included 'student', 'school', 'principle', 'blockchain', and 'course', etc., which suggests that the principles of blockchain covered in the education program are restricted. Lastly, Topic-4 included 'education', 'level', 'completeness', 'difficulty', and 'improvement'. This indicates that the topic suggests that the level of difficulty needs to be added to the education program for completeness.

5. Discussion

We developed an educational program based on learning games in an effort to encourage elementary students to have more interest in blockchain and to foster the talent of those well-versed in blockchain technology. The education program was developed in accordance with the instruction design steps of the ASSURE model that emphasizes the utilization of instructional media.

We first analyzed learners to select elementary school learners. In the survey, fewer South Korean elementary school students were found to favor engineer or software developer jobs directly related to computing technology than other school-age groups. Furthermore, in the digital literacy analysis of elementary school students, South Korean elementary students were found to have difficulties with organizing/creating information or converting it into different formats in general. It is necessary to underscore competencies for creating new things beyond playing games and solving problems with given information. It is also worthwhile studying the relevance of this education program to digital literacy. Since blockchain has the high latent potential to promote coordination, cooperation, and trust with technologies, artifacts, and cultural forms as the next step in a human tradition, we need to put in a great deal of effort encouraging learners to acquire sufficient digital literacy of their secure digital infrastructure, public access to online resources, and public computing [34].

Secondly, educational objectives were specified. Instructional objectives were described in detail according to Mager's [19] A-B-C-D principle. It was concluded that it is important to conduct learner-centered education and teach students to express what has been learned in their own language. This approach allowed the learners to reflect on what they learned in open-type sentences in worksheets. When this program was applied in practical arts classes or creative activities programs, improvement in problem-solving skills and digital literacy of learners was specified as the standard applicable to the assessment of the fulfillment of such educational objectives. If the program effectiveness is analyzed as to changes in those competencies when this education program is applied to students in subsequent studies, meaningful insight may be obtained.

Thirdly, with regard to the selection of educational methods, media, and materials, we examined previous studies on the blockchain education program to analyze duplicated elements and define an educational method design strategy combined with lecture, experimental learning, gamification, problem-based learning, and simulations. Recognizing the significance of both unplugged worksheets and online-compatible worksheets for elementary school learners, we also developed worksheets usable even in remote lessons, using the Liveworksheets platform. Additional studies are needed to scale up the learning games proposed to be deployable, not only in offline classes, but also in online learning environments. Using the additional competencies of innovative emerging technological applications, such as blockchain, educators in the online and distance learning system, which has flourished with the use and support of the ICTs, should play a crucial role in terms of delivery instruction and interactive communication [35]. Within an educational context, blockchain can empower individual learners to manage and share details of their credentials without a trusted intermediary through an indisputable mechanism to verify that the data has existed at a moment [36].

Fourthly, educational content was designed and teaching aids were utilized. To that end, the reference literature covered in Step 3 was consulted. Then, the validity of the developed educational contents and tools was assessed by experts. In the analysis, all CVR values were found to be 0.62 or higher, which indicates that the contents and tools were viable. However, the CVR of the durability of the developed educational tools tended to be somewhat lower, which suggests that the tools need to be made of sturdier and longer-lasting materials.

Fifthly, in Step 5, how to motivate learners to engage more in games was analyzed in relation to previous studies examined in Steps 3 and 4. It was found that a reward in coins was needed. However, such coins need to be developed from the ground up in consideration of the economic efficiency of physical coin material. Chivu et al. [37] suggested that a reward system has a critical role in enabling learners to be actively involved in learning blockchain technologies. In terms of the potential for blockchain to represent an innovative technological paradigm shift that helps security, simplification, and efficiency, it is necessary to instill understanding of the core of blockchain in education beyond infancy [37].

In the last step, the developed education program was evaluated and improvement opportunities were identified. In the analysis of experts' feedback on the strengths and weakness, the assessed level with the learning game design was high. Yet, there was also feedback that the level of difficulty needed to be increased and the game design expanded to allow students of a wider range of age groups to participate in the education program. Therefore, more in-depth study is deemed necessary to add level of difficulty to the program design so that the program can be compatible with learners of more diverse literacy levels. According to previous studies that have tried to develop teaching materials for integrated education for elementary school students, dynamic materials that lead to self-directed learning are helpful to effectively bring about learning outcomes [27,38]. Some studies have found that learning models focusing on motivation and creativity might increase the potential of learners during their understanding of cutting-edge technologies [37,39]. Though this paper can provide a basis for further research to develop or improve learning programs using new technological concepts underlying trends of industries, there are still challenges concerning how the learning content, materials, or models can be contextualized depending on individual learning needs.

6. Conclusions

Blockchain, promoted as one of the foundational technologies for the fourth industrial revolution, is becoming ever more important [40]. The compromised trust of public institutions and the financial crisis have prompted many people to look for new transactional arrangements, and the concept of blockchain guaranteeing trust through decentralization has emerged as a new stream of innovation [41].

Many attempts have recently been made to incorporate blockchain principles into education, but the method of teaching elementary school students has yet to be studied [14]. Thus, this study has proposed an education program that can teach blockchain principles using games. The education program was developed based on the ASSURE model and was intended to evaluate the possibility of field application.

The blockchain education program developed consists of three lessons: Lesson 1 covers the basic concepts and principles of blockchain, Lesson 2, public blockchain, and Lesson 3, private blockchain. Each lesson includes learning games that are to be played by students after teachers deliver a lecture and organize worksheet activities. By playing the learning games, students can spontaneously improve their understanding of blockchain concepts. When experts' feedback on the developed education program was summed up, the gamification method adopted to teach relatively complicated concepts to elementary school learners through learning games was found to be effective. However, improvement opportunities were also pointed out, for example, that the content of the education program was somewhat limited and the level of difficulty and learner level-specific learning program were not included in the content. In addition, the ultimate goal of the education program, defined as the fostering of talents for sustainable future development with quality education programs, requires the effectiveness of the program to be analyzed in reference to the SDGs in subsequent studies. Subsequent activities following this study will focus in depth on how to boost the extensibility of the education program and foster talent for sustainable future development. Unlike previous studies that have leaned toward statistical analysis of quantitative data, this study is significant in that it has attempted to utilize models and visualize unstructured data contributed by experts. It is hoped that this article will provide insight into education programs designed to teach cutting-edge technologies to elementary students who are likely to be excluded from the scope of such programs.

Author Contributions: Conceptualization, methodology, investigation, validation, formal analysis and writing—original draft preparation, E.C. and writing, review and editing, Y.C. and supervision and project administration, N.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2019R1I1A3A01062789). and, this work was supported by the Korea Foundation for the Advancement of Science and Creativity (KOFAC) grant funded by the Korea government (MOE).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to a confidentiality agreement.

Conflicts of Interest: E.C., Y.C. and N.P. declare no conflict of interest.

Appendix A

Table A1. Educational Game Activities for the Element of Learning Game.

Periods	Gamified Components	Learning Activities
1	Specific objectives	To help players understand the principle of consensus mechanism among blockchain concepts. The game is won when all the cards of the opponent are taken.
	Rules	Two sets of 18 cards in total, including six white, blue, and red cards, respectively, are needed. The cards are painted in respective colors on one side; and six different cryptocurrency symbols are printed on the other side. Logos of cryptocurrencies used in reality are used to stimulate the interest of learners and allow them to experience the real use of blockchain indirectly.
	Interactive problem solving	Two people usually play the game, but it can also be played while discussing in a team. If the players play in a team battle, they can increase their unity by scoring points for each team.
	Adaptive challenge	Teachers need time to explain the rules to the students before the game so that they can understand the rules that depend on the color of the cards.
	Ongoing feedback	During the game, the teacher helps the game progress and develops the game by investigating students' difficulties during the game. Because timing is important, this feedback increases the completeness of the game through quick response.
	Uncertainty	Students may develop suspense about unpredictable matches during the game, leading to motivation for the game. Appropriate rewards are given to ensure that the tension in the game leads to learning motivation.
	Control	It is necessary to create an environment where students concentrate on the games to learn blockchain principles. Due to the nature of the educational game, it will be mainly played in the classroom, and although the game has rules, we encourage students to develop the game by making rules.
	Sensory stimuli	Through unplugged education activities, five senses were used to play games with creativity during a game. Elementary school students are especially crucial for developing the five senses, so games that can utilize senses, such as sight, touch, and hearing, are essential [42].

Table A1. *Cont.*

Periods	Gamified Components	Learning Activities
2	Specific objectives	This game aims to help students understand the principles of the public blockchain and the characteristics of the openness and transparency of the blockchain. In the process of recording all transactions in the ledger, everyone can learn the shortcomings of public blockchain in situations where the game is delayed. On the other hand, the game is structured so that players can understand the advantage that it is difficult to forge because every player records books.
	Rules	Students and teachers need ledgers, dice, markers, game boards, and coins. Since each player needs one marker, the teacher should prepare enough to fit the number of students and make four members of a team.
	Interactive problem solving	The process of recording all transactions on the ledgers can be cumbersome, but students cannot cooperate and show their books to other students in the middle. It is because it can increase the possibility of sharing wrong transactions. Students can create their space during the game where they can prepare telescopes or focus on games to avoid missing a deal. Thus, when faced with a problem, students can develop various measures to develop the power to solve them independently.
	Adaptive challenge	The game is similar to Monopoly, a boardgame, with the possibility that more coins can be obtained through double deals or land sales when there are not as many coins as other students. It provides students with a chance to get up again even if they are losing, rather than being easily frustrated.
	Ongoing feedback	Teachers should try to solve the problem by quickly investigating students' inconvenience or incomprehension while playing the game.
	Uncertainty	Due to variables such as double trading and land sales, it is difficult to predict who will be the winner and how the game will proceed.
	Control	In order to allow all students to see the dice, students create a playing space where they can sit in a circle or see each other; and they can also play games in a larger space, not in the classroom. All students can play games actively and even decorate the game space like a bank to arouse interest.
	Sensory stimuli	The process of all students watching one dice throw or making a deal and writing it down on the ledgers is a process that stimulates five senses. Some students may use tablet PCs or smartphones during the bookkeeping process. It is up to the students themselves to write by hand or to use IT devices. Each child may have a different stimulating process, and the learning effect may vary accordingly [43].

Table A1. *Cont.*

Periods	Gamified Components	Learning Activities
3	Specific objectives	The purpose of this game is to help students understand the principles of private blockchain.
	Rules	The rules of the game are basically the same as the public blockchain. However, the different point is that the ledger is not written by all students, but rather a few reliable students are selected. During the game, transactions are impossible without the approval of the students who write down the ledgers.
	Interactive problem solving	Students in writing the ledgers role work together to prepare ledgers. When players play games, they cannot trade without their approval. During this process, brokers can consult with each other to approve or deny transactions and solve problems together. Players can solve problems in the event of a transaction by consulting with a broker. Through these situations, students can develop problem-solving skills through communication.
	Adaptive challenge	The same challenges are given because this game is played in essentially the same way as a public blockchain game. Those who lack coins can consult with a broker to solve this problem, and in this process, it can be an opportunity to learn this aspect of the private blockchain.
	Ongoing feedback	Teachers should quickly identify problems that arise while brokers record transactions and host players' games and provide appropriate assistance. Rather than simply solving problems, it is crucial to teach them how to solve them indirectly. Teachers should also be careful not to cause problems that students cannot solve or are in an emergency during the game.
	Uncertainty	A few of the students may secretly consult with a broker to obtain more coins by expedient behaviour. Since these variables can have a strong influence on the game's win or loss, it can be seen that there is stronger uncertainty than in a public blockchain game.
	Control	It is necessary to be cautious when selecting intermediaries to create a game environment. Selecting students with a strong sense of trust can facilitate the progress of the game. However, when selecting students who lack trust from the other students, the game progresses slowly, and there can be a war of nerves between brokers and players. There is no right way between the two, but it is better to choose considering game time or environment.
	Sensory stimuli	Players and brokers will have different sensory stimuli because their roles are different in the game. Various stimuli in games increase the effectiveness of education and help develop.

References

1. Park, S.J.; Kim, S.K.; Rachmatullah, A.; Ha, M.S.; Yoon, H.S. The Effects of Science Class Applied Gamification Contents. *Korean Soc. Sch. Sci.* **2018**, *12*, 75–84.
2. Sanlad, M.A. Introduction. In *Determinants in Distance Education during the COVID-19 Pandemic*; GRIN Verlag: Munich, Germany, 2021; pp. 1–6.
3. Ministry of Education Republic of Korea. *2015 Revised National Curriculum*; Ministry of Education Republic of Korea: Seoul, Korea, 2015; pp. 48–87.
4. Gamification: How Competition Is Reinventing Business, Marketing & Everyday Life. Available online: https://mashable.com/archive/gamification (accessed on 24 September 2020).
5. Malamed, C. Book Review: 'The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education' by Karl Kapp. *eLearn* **2012**, *2012*. [CrossRef]
6. Kim, J. The Development and Implementation of a Gamification-Applied Museum Education Program: Case Study Linked to Elementary School. Master's Thesis, Kyunghee University, Seoul, Korea, 2014.

7. Jeon, Y. The Effect of the Gamification Factor Applied Lessons on Academic Interest and Academic Self-Efficacy: Focused on the High School Technology Class. Master's Thesis, Korea National University of Education, Cheongju, Korea, 2016.
8. Randel, J.; Morris, B.; Wetzel, C.; Whitehill, B. The Effectiveness of Games for Educational Purposes: A Review of Recent Research. *Simul. Gaming* **1992**, *23*, 261–276. [CrossRef]
9. Iannotti, R.J. Effect of Role-taking Experiences on Role Taking, Empathy, Altruism, and Aggression. *Dev. Psychol.* **1978**, *14*, 119–124. [CrossRef]
10. Sitzman, T. A Meta-analytic Examination of the Instructional Effectiveness of Computer-based Simulation Games. *Pers. Psychol.* **2011**, *64*, 489–528. [CrossRef]
11. Yoon, J.; Koh, H. A study on the development of a digital Art Museum Education Program through the Use of Gamification. *Art Educ. Rev.* **2020**, *74*, 229–249.
12. Jung, J.-Y.; Lee, M.-H. Analysis of Learning Immersion and Class Participation in Gamification-based Classes. *J. Educ. Innov. Res.* **2021**, *31*, 163–187.
13. Kim, J.T. Proposal for Direction of Blockchain Education on Gamification. *J. Korean Soc. Comput. Game* **2019**, *32*, 15–23. [CrossRef]
14. Son, M. Effective Educational Tool to Teach Blockchain Easily. *Aprop. Tech.* **2019**, *11*, 36–43.
15. Jung, Y.; Kim, J.; Park, N. Understanding and Education Measures of the Prevention of Forgery and Falsification of Blockchain for Elementary School Students. *JKAIE* **2019**, *23*, 513–520. [CrossRef]
16. Kim, J.; Park, N. Blockchain Technology Core Principle Education of Elementary School Student Using Gamification. *JKAIE* **2019**, *23*, 141–148. [CrossRef]
17. Heinich, R.; Molenda, M.; Russell, J.D.; Smaldino, S.E. *Instructional Media and Technologies for Learning*, 5th ed.; Prentice Hall: Hoboken, NJ, USA, 1996; p. 248.
18. Gagne, R.M. Educational Technology and the Learning Process. *Educ. Res.* **1974**, *3*, 3–8. [CrossRef]
19. Mager, R.F. *Preparing Instructional Objectives*, 3rd ed.; Fearon Publishers: Palo Alto, CA, USA, 1962; pp. 10–53.
20. Karakis, H.; Karamete, A.; Aydin, O. The Effects of a Computer-Assisted Teaching Material, Designed According to the ASSURE Instructional Design and the ARCS Model of Motivation, on Students' Achievement Levels in a Mathematics Lesson and Their Resulting Attitudes. *Eur. J. Contemp. Educ.* **2016**, *15*, 102–113. [CrossRef]
21. Mehmet, A. Evaluation of the Effectiveness of English Language Instruction based on the ASSURE Model. *E-Int. J. Educ. Res.* **2021**, *12*, 195–211. [CrossRef]
22. Ministry of Education Republic of Korea. Available online: https://moe.go.kr/sn3hcv/doc.html?fn=5377e11fe37f8b343454e2831fea37f9&rs=/upload/synap/202203/ (accessed on 24 February 2021).
23. Yi, H.S.; Kim, S.; Kim, H.S.; Lee, W.J.; Lim, S.A.; Park, S. *2018 National Assessment of Digital Literacy of Korean Elementary and Middle School Students*; Korea Education and Research Information Service: Daegu, Korea, 2019; pp. 82–167.
24. Yi, H.S.; Kim, S.; Lee, W.J.; Kim, H.S. *2019 National Assessment of Digital Literacy of Korean Elementary and Middle School Students*; Korea Education and Research Information Service: Daegu, Korea, 2019; pp. 77–142.
25. Jung, J.M.; Yi, H.S.; Kim, S.; Lee, W.J.; Ryu, G.G.; Kim, K.A.; Cho, K.B.; Gu, C.D. *2020 National Assessment of Digital Literacy of Korean Elementary and Middle School Students*; Korea Education and Research Information Service: Daegu, Korea, 2021; pp. 39–117.
26. Xing, L. A Small Java Application for Learning Blockchain. In Proceedings of the 2018 IEEE 9th Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON), Vancouver, BC, Canada, 1–3 November 2018.
27. Choi, J.; Koo, D.H. Development of Unplugged Program for Elementary Students' Blockchain Learning. *KJEE* **2020**, *31*, 273–289. [CrossRef]
28. Dettling, W.; Schneider, B. Bloxxgame—A Simulation Game for Teaching Blockchain. In Proceedings of the International Conference on Games and Learning Alliance 2020, Laval, France, 9–10 December 2020.
29. Kaden, S.R.; Lingwall, J.W.; Shonhiwa, T.T. Teaching Blockchain through Coding: Educating the Future Accounting Professional. *Issues Account. Educ.* **2021**, *36*, 281–290. [CrossRef]
30. Lawshe, C.H. A Quantitative Approach to Content Validity. *Pers. Psychol.* **1975**, *28*, 563–575. [CrossRef]
31. Shim, S.; Baek, Y.; Lee, Y.; Ham, E.; Byun, K.; Kim, N.; Park, J. *Play and Early Childhood Education*; Knowledge Community: Gyunggi-do, Korea, 2010; pp. 62–67.
32. Gilster, P. *Digital Literacy*; Wiley Computer Pub.: New York, NY, USA, 1997; p. 1.
33. Shute, V.J.; Ke, F. Games, Learning, and Assessment. In *Assessment in Game-Based Learning*; Springer: New York, NY, USA, 2012; pp. 43–58.
34. Alfano, M. Elections, Civic Trust, and Digital Literacy: The Promise of Blockchain as a Basis for Common Knowledge. *SATS* **2021**, *22*, 97–110. [CrossRef]
35. Chivu, R.-G.; Popa, I.-C.; Orzan, M.-C.; Marinescu, C.; Florescu, M.S.; Orzan, A.-O. The role of blockchain technologies in the sustainable development of students' learning process. *Sustainability* **2022**, *14*, 1406. [CrossRef]
36. Park, N. STEAM education program: Training program for financial engineering career. *Int. J. Pure Appl. Math.* **2018**, *118*, 819–835.
37. Lim, E.; Kim, S.; Lim, H.; Kim, B. Development and application of a design thinking program that utilizes technology as an educational model for creativity and convergence competence. *Korean J. Gen. Educ.* **2021**, *15*, 29–49. [CrossRef]
38. Park, N. The core competencies of SEL-based innovative creativity education. *Int. J. Pure Appl. Math.* **2018**, *118*, 837–849.
39. Sharma, R.C.; Yildirim, H.; Kurubacak, G. (Eds.) *Blockchain Technology Applications in Education*; IGI Global: Hershey, PA, USA, 2020; pp. 80–96, 126–169.

40. Park, N.; Hu, H.; Jin, Q. Security and Privacy Mechanisms for Sensor Middleware and Application in Internet of Things (IoT). *Int. J. Distrib. Sens. Netw.* **2016**, *12*, 2965438. [CrossRef]
41. Lee, D.; Park, N. Blockchain based Privacy preserving Multimedia Intelligent Video Surveillance using Secure Merkle Tree. *Multimed. Tools Appl.* **2021**, *80*, 34517–34534. [CrossRef]
42. Mitts, M. Effect of Sensory Stimulation in Physical Activity on Academic Achievement and Classroom Behavior in Elementary Students. Ph.D. Thesis, University of Arkansas, Fayetteville, NC, USA, 2018.
43. Ma, M.-Y.; Wei, C.-C. A Comparative Study of Children's Concentration Performance on Picture Books: Age, Gender, and Media Forms. *Interact. Learn. Environ.* **2016**, *24*, 1922–1937. [CrossRef]