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A constructivist and pragmatic training framework for blockchain education for IT practitioners

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Abstract
Blockchain is a newly emerging technology in the past decade that has significantly impacted various aspects. "Scientific popularization" among IT practitioners on this technology and its use cases become a pressing need. However, constructing an effective blockchain teaching approach for this purpose is a challenging task. A training framework consisting of constructivist and pragmatic approaches is proposed, aiming to provide IT practitioners with an effective Teaching and Learning (T&L) process about blockchain on both theory and application aspects. The outcomes of this study are to 1) propose an effective teaching methodology, 2) assess the effectiveness of constructivist and pragmatic approaches and 3) extract the elements facilitating blockchain T&L. Mixed quantitative and qualitative research methods were adopted, including questionnaires and knowledge quizzes. 1267 participants were involved in the training that implemented the proposed framework. Their performance and responses indicated that the framework is effective and flexible. The findings from this empirical research can serve as a reference for educators in blockchain to implement a systemic approach that facilitates the T&L process and improves the field of blockchain and education in the future.

Keywords Adult education · Blockchain · Constructivism · Pragmatism · Model curricula

1 Introduction

Blockchain is an emerging information technology in recent years that has significantly influenced several domains, such as business operations, education, and government administration (Mohanta et al., 2019; Chen et al., 2018). At present, numerous indus-

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try sectors have applied blockchain technology, including finance, health, education, and supply chain (Casino et al., 2019; Ghosh, 2019; Hölbl et al., 2018; Yumna et al., 2019; Tama et al., 2017). Application examples include a blockchain-based smart contract system for healthcare management to streamline complex medical procedures (Khatoon, 2020), a non-face-to-face blindness-proof document storage system from Kookmin Bank in Korea (Oh & Shong, 2017), a permission blockchain system for verifiable academic credentials (Arenas & Fernandez, 2018), and a supply chain system for traceability, regulation and anti-counterfeiting (Lau et al., 2021). With the utilization rate and public awareness of blockchain, cultivating IT professionals to cope with the challenges in the blockchain arena becomes a pressing need.

Nowadays, there exist various blockchain teaching and learning (T&L) materials and approaches in the community. They are omnifarious and target various types of audiences (Negash & Thomas, 2019; Udokwu et al., 2022; Liu, 2018; Gutowski et al., 2022; Stern & Reinstein, 2021; Rao & Dave, 2019; Bornelus et al., 2019). However, the task of developiconstructivist and pragmatic training framework for blockchain educationlation ip challenging. The balance between theoretical and practical knowledge is a factor to be taken into consideration in blockchain education for "scientific popularization" among IT practitioners. It should be noted that IT practitioners are interested in new technology exploration and have a fundamental basis of applying technologies efficiently. When designing the training framework, this background of our audience was considered thoroughly.

Accordingly, we propose a training framework that includes seminars and workshops, and T&L materials, which aims to overcome the blockchain education challenges for educating IT practitioners on basic blockchain knowledge in both theoretical and practical aspects, including blockchain concepts, use cases and applications in an incremental manner. Our framework comprises a 1-day lecture spanning 7.5 hours covering fundamental blockchain technology concepts, theories, and use cases. After that, there is a 2-day workshop spanning 15 hours, in which participants gain hands-on experience in developing a decentralized application (DApp) from scratch. Due to the fact that IT practitioners, who have computational thinking and coding skills, are keen on the technical aspects of the technology, the workshop helps strengthen the participants' understanding of the technology and how it can be applied in IT systems and their workplaces. Some pedagogical research (Ma & Nickerson, 2006; Xu et al., 2013; Liu et al., 2019; Han et al., 2021; Al Kaabi et al., 2016; Hassan et al., 2022) has shown that hands-on laboratories are crucial to the success of computing education. Therefore, integrating hands-on workshop into our framework provides comprehensive training to the participants.

In addition, the training framework is designed using constructivist and pragmatic approaches. These two teaching approaches were individually found effective in computer science education and bring significant T&L outcomes (Wulf, 2005; Becker, 2000; Dolgopolovas & Dagiene, 2021; Asunda, 2014). However, there is a lack of research on using both constructivist and pragmatic approaches in computer science education, especially in the field of blockchain.

The aims of this research are to construct an effective approach (i.e., the training framework) using constructivist and pragmatic approaches to teach blockchain to IT practitioners, especially blockchain novices. Also, through the training framework to study the consequences of adopting constructivist and pragmatic approaches in blockchain education and extract the elements which may facilitate the T&L process. Four research questions could be answered in this research:

(i) What methodology can effectively be adopted for blockchain education for IT practitioners?
(ii) What are the merits of using constructivist and pragmatic approaches in blockchain education?
(iii) What are the essential elements that facilitate T&L processes in Blockchain?

Our framework has been adopted in over 30 training seminars and workshops with a total of over 1,200 participants. The details of the framework will be given in Section 3. To assess the effectiveness of our framework, quantitative and qualitative research methods are adopted, which include knowledge quizzes and feedback questionnaires. The analytical results of the knowledge quizzes and feedback questionnaires will be given in Section 4.2. Based on the results, the effectiveness of the framework, the merits of using constructivist and pragmatic approaches, and essential elements of facilitating blockchain education will be discussed in Section 5.

2 Background

2.1 Importance and potential of blockchain

Blockchain technology has evolved rapidly in recent years. According to a bibliometric study (Firdaus et al., 2019), the quantity of publications related to "blockchain" has shown significant growth from 2013 to May 2018. Another bibliometric study (Dabbagh et al., 2019) showed that the publications related to blockchain topics, including Bitcoin, Blockchain, Cryptocurrency, Ethereum, and Smart Contract have been increasing continuously from 2013 to November 2018. The number of citations to Blockchain papers has also been growing drastically since 2017. Furthermore, a blockchain-related publication (Capetillo, 2018) also discovered that there are over 2000 articles with the word "Blockchain" in the title appearing in Google Scholar in 2018.

Besides, blockchain technology is widely used to implement IT applications and solutions in different scenarios. Due to blockchain's characteristics and advantages, many researchers have started to study how to apply blockchain in real-life use cases. They presented several blockchain-based applications and models and evaluated their feasibility. This atmosphere made the number of publications related to blockchain-based applications keep increasing continuously in different aspects such as education (Alammary et al., 2019), business (Frizzo-Barker et al., 2020), healthcare (Agbo et al., 2019), supply chain (Queiroz et al., 2019), Internet of Things (Kamran et al., 2020).

Apart from its popularity in the academic community, Deloitte's 2020 Global Blockchain Survey (Deloitte Insights, n.d.) observed that blockchain is becoming more critical within the industry. The survey polled a sample of 1,488 executives and practitioners in 14 countries. According to the survey report, 39% respondent organizations already brought blockchain into production in 2020, while there were only 23%

in 2019. Also, 88% respondents thought that blockchain technology would achieve mainstream adoption unexpectedly and be scalable in broad disciplines, while 86% in 2019 and 84% in 2018. The survey result indicated that blockchain is also getting popular in the industry sector.

2.2 Constructivism and pragmatism

Constructivism is an educational philosophy that believes knowledge is non-objective and is best acquired by the learner's reflection and active construction (Yilmaz, 2008; Ültanir, 2012; Van Geert, 2017; Jaleel & Verghis, 2015; Steffe & Gale, 1995; Jones & Brader-Araje, 2002), while pragmatism is an educational philosophy that believes knowledge has no predetermined certainties but rather, is best acquired by practicality, experimentation, and real-world experience (Sharma et al., 2018; Adeleye, 2017; Garrison & Neiman, 2003; Dewey, 1986; Alexander, 2012).

Constructivism and pragmatism maintain different perspectives on the field of Epistemology. Constructivism believes the meaning of knowledge is socially and culturally mediated, which means the meaning of knowledge will be altered based on the convention of sociality and cultural development (Yilmaz, 2008; Steffe & Gale, 1995; Crotty, 1998; Gergen, 1995). It also believes that knowledge is not a product of learning, but knowing is a process (Jones & Brader-Araje, 2002; Jonassen, 1991; MİSHRA, 2014). Constructivist learners should individually, collectively, and actively construct their own knowledge (Ültanir, 2012; Jones & Brader-Araje, 2002).

On the other hand, pragmatism believes the meaning of knowledge is assigned by practical consequence and usefulness. Pragmatists hold a point of view that the meaning of knowledge is not eternally in truths. It will be altered based on the factors of times, places, and situations (Sharma et al., 2018; Adeleye, 2017; Diggins, 1995; James, 1975). The meaning of knowledge will be true if and only if it is useful to humans or can individually promote the good and welfare of society (Adeleye, 2017; Wood & Smith, 2008). Pragmatism emphasizes that activity is important in generating learning experience, and the knowledge can be well-gained by doing, also known as "learning by doing" (Kivinen & Ristelä, 2002; Roberts, 2012). However, there is a similarity among these two philosophies, which both believe that knowledge is temporary and alterable.

Apart from Epistemology, constructivism and pragmatism have different opinions on learning objectives, the role of teachers, and methods to construct learning environments. The learning objective of constructivism is to let learners be able to construct their own knowledge through a learning experience (Schcolnik et al., 2006; Bada & Olusegun, 2015), while the objective of pragmatism is to let learners can apply knowledge in performing skills in solving real-world applications by learning from experience (Elkjaer, 2009; Davidova & Kokina, 2014). The significant distinct point is the focus on knowledge and skill. Knowledge and skill are qualities with different definitions. According to the Knowledge, Skills, and Abilities (KSA) framework (Cheney et al., 1990; Stevens & Campion, 1994; Kang & Ritzhaupt, 2015) , knowledge is defined as the body of information that can be applied to functional performance directly, and skill is defined as competence in performing psychomotor acts related to the proficiencies of technology. On top of the definition of knowledge and skill, constructivism is more focused on knowledge learning and prioritizing the ability of critical thinking and problem-solving on knowledge application and construction. On the other hand, pragmatism is more focused on skill learning and prioritizing to use of knowledge as a means to solve problems practically.

One more significant difference is the role of the teacher. The constructivist teacher acts as a facilitator in the T&L process, and they facilitate the T&L process by directing the student to have individual and collective thinking on the meaning of knowledge (Richardson, 2005, 1997). The constructivist teacher should not directly provide solutions or answers to the students' challenges but facilitate the students' exploration and discovery process through guidance and support. Furthermore, pragmatic teachers teachers are supposed to act as a facilitator and collaborators, and they facilitate the T&L process by guiding the students to solve a problem by providing a practical and experimental experience (Sharma et al., 2018; Adeleye, 2017). In most circumstances, the teacher will demonstrate the process of constructing solutions and experimentation. Students will acquire hands-on experience in problem-solving by following their teacher's lead. This approach will enable them to develop the skills necessary for addressing real-world issues. In short, constructivist and pragmatic teachers are the facilitators in the T&L process as well, but pragmatic teachers simultaneously are collaborators.

Although these two educational perspectives seem to have differences in nature, they can complement each other. It leaves a possibility that the two educational perspectives can be considered during curriculum design. Particularly, blockchain education for IT partitioners, in which equal emphasis should be put on both knowledge and skill, should reference these two perspectives during the curriculum and T&L process. Table 1 summarized the perspectives among constructivism and pragmatism.

2.3 Existing learning approaches in blockchain education

As blockchain technology becomes popular and important, cultivating IT professionals to cope with the challenges becomes a pressing need these days. Many blockchain T&L materials and approaches are available in the community. The materials and approaches are omnifarious and generally sourced from educational institutions or industries.

Presently, a number of universities provide organized programs designed to educate individuals on blockchain (Gutowski et al., 2022). Learners might obtain a certificate or degree upon completion of their studies. In addition, universities provided structured educational resources and methodologies for teaching blockchain, including courses (Stern & Reinstein, 2021; Gutowski et al., 2022) and hands-on laboratories (Rao & Dave, 2019; Bornelus et al., 2019). Universities occasionally provide innovative T&L materials and approaches for educating blockchain such as a 7-scenario design for teaching blockchain technology to non-technical students (Negash & Thomas, 2019), a survival game for blockchain education (Udokwu et al., 2022), and a Java application for learning blockchain (Liu, 2018). Besides, there are tonnes of self-paced online blockchain courses from Massive Open Online Course (MOOC) platforms such

Table 1 Comparison table of constructivism and pragmatism

Aspect	Constructivism	Pragmatism
Epistemology	Meaning of knowledge is socially and culturally mediated	Meaning of knowledge is assigned by practical consequence and usefulness
Focal Point	Knowledge	Skill
Key Words	Construct; Knowledge; Individually; Collectively	Practice; Skill; Practically
Prioritization	Critical thinking and problem-solving ability on applying knowledge	Skill to use knowledge solving problem practically
Relevant T&L Methods	- Case studies	- Evidence-based practice
	- Group discussions/activities	- Experimentation
	- Probing questions	- Learning-by-doing
	- Project-based learning	- Play way method
	- Role-playing	- Simulation-based learning
	- Scaffolding	
	- Storytelling	
Role of Teacher	Facilitator	Facilitator & collaborator
Study Objective	learners be able to construct their own knowledge	learner can apply knowledge in performing skills in solving real-world applications
Teaching Strategies	Problem solving-oriented	Problem solving-oriented

as edX, Coursera, and FutureLearn. The courses span the range from introductory to advanced levels, encompassing a wide variety of topics, including fundamentals, applications, and security. Learners are given the freedom to pick a course that matches their expectations, allowing for flexibility.

However, we discovered that most of the blockchain T&L materials and approaches target non-technical audiences, such as people from the business and finance-related fields. They tend to cover theoretical and managerial knowledge rather than both the application and technical aspects of blockchain. These T&L approaches enable audiences to understand what blockchain is and when they should apply it, but they may not provide details on how the applications can be realized by the technology. In addition, MOOCs require learners' self-motivation and lack opportunities to engage with peers to discuss and share insights. Furthermore, it is remarkable that blockchain technology's enormous educational potential has yet to be fully exploited (Gutowski et al., 2022).

Therefore, we propose a training framework for audiences who are normally IT practitioners with certain computing and technical backgrounds but are not familiar with blockchain technology. In the framework, the audiences will undergo a combination of seminar and workshop to study the knowledge of blockchain incrementally, from fundamental concepts and use cases, to basic decentralized application development. Additionally, this study presents a comprehensive methodology for developing a blockchain T&L framework, which can be employed as a guide for applying a systematic approach that enhances the blockchain T&L process.

3 The framework

3.1 Objectives

Our training framework consists of seminar and workshop, and Table 2 summarises the objective of the training framework. The seminar introduces fundamental ideas of blockchain, which focuses on theoretical aspects of blockchain. Since IT practitioners are more interested in applying blockchain technology in their workplace, major blockchain solutions and frameworks for application development are introduced to them. Through case study activities, the audience can understand how to realize the use cases for their organizations and determine if blockchain is the appropriate technology to be integrated into their new/existing systems. For the workshop, audiences will be given hands-on experience in creating a decentralized application (DApp). During the workshop, audiences will be guided to complete a DApp from starting up a blockchain network to implementing smart contracts and a web-based front-end. This learning experience helps deepen the audiences' understanding of the knowledge technology and enhance their practical skills for developing blockchain-based solutions. The overall objective of the training framework is to introduce to the audiences various aspects of blockchain, including theories, applications and use cases. It aims to enhance the readiness of the audiences to become decision-makers and developers for blockchain-based solutions. A combination of seminar and workshop allows an experiential learning experience through group discussion and presentation, as well

Table 2 Objectives of the training framework

Section	Objectives
Seminar	Introduce the fundamental knowledge of blockchain.
	Introduce major blockchain solutions and frameworks for application development.
	Introduce the assessment, readiness, and selection skills for establishing blockchain-based projects.
Workshop	Introduce the architecture of blockchain frameworks and data transaction models.
	Enhance audiences' practical skills of developing blockchain-based application.
	Introduce the design patterns and security considerations in blockchain application development.
Overall	Enable the audiences to understand the theories, applications and use cases of blockchain.
	Facilitate the T&L process of blockchain education for IT practitioners.
	Provide an implementation example of a realist application to help audiences understand the architecture of blockchain-based application and blockchain network.

as hands-on setup and development of blockchain systems, in order to strengthen the audiences' understanding of the technology.

3.2 Design

3.2.1 Model design

To deliver a training framework that is effective and satisfactory for the audience and instructor, ADDIE model (Peterson, 2003) is adopted in the development of the training framework. The details of the ADDIE model are shown in Fig. 1.

The initial phase of ADDIE model is Analyze, which involves identifying the needs and training requirements of stakeholders. Initially, a set of training requirement specifications are provided by the stakeholders. Based on the requirements, a survey is conducted to extract the audiences' expectations. Subsequently, the training framework is designed based on the results extracted from the analysis. The learning objectives, educational strategies, training content outlines, evaluation methods, and schedules are included in this phase. Then, the Design phase involves designing, structuring and developing the training contents (i.e., presentation slides and lab manual), tools (i.e., virtual machine image) and evaluation assessments (i.e., surveys and quizzes). A validation process is conducted to ensure the contents are unanimous with the training objectives and educational strategies. In the Implementation phase, the training course

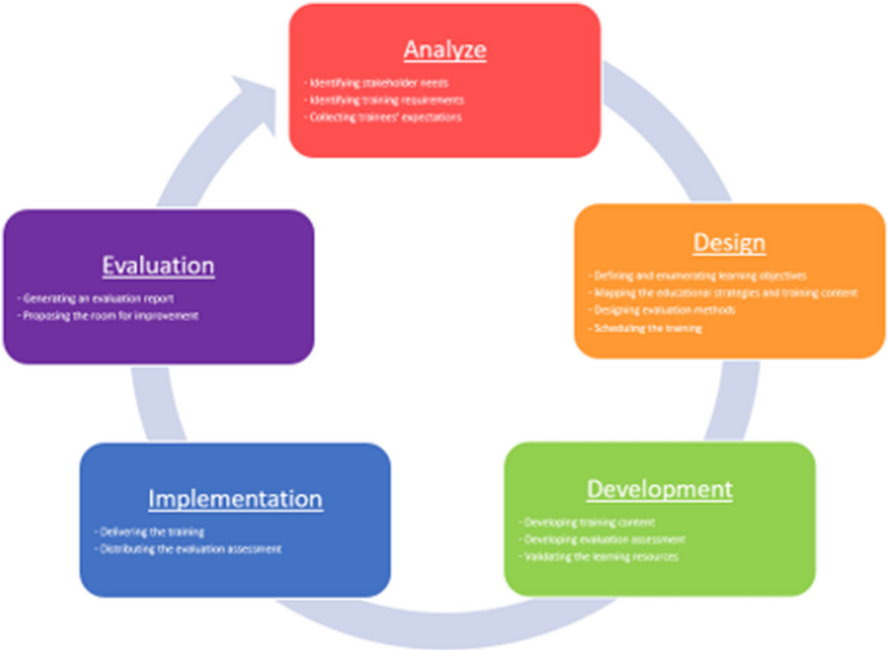

Fig. 1 ADDIE model adopted in this training design

is delivered to the audiences. At the end of the training, evaluation assessments are distributed to audiences, and the data from evaluation assessments are analyzed to assess the effectiveness of training and the degree of satisfaction among audiences. The results are investigated with the aim of refining the training framework.

3.2.2 Strategies design

Constructivism and pragmatism. The training framework is separated into two sections: seminar and workshop. The educational natures of these two sections are different based on their respective objectives. Seminar is intended to provide introductory blockchain technology cognition to audiences and enable them to properly plan and manage blockchain-related projects. On the other hand, Workshop is designed to deepen their cognition with respect to blockchain technology and enhance their practical skills in developing blockchain-related applications. Therefore, constructivism is considered suitable for seminar, while pragmatism is adopted for workshop.

Problem-based learning. In order to effectively realize constructivism, a problem-based learning approach has been amalgamated into seminar section. Specifically, case studies and group discussion activities are incorporated as a portion of seminar and take up a significant duration. Through engaging in case studies and group discussions, audiences are encouraged to collaborate and deliberate, and make decisions on applicability of the blockchain technology to potential applications. The process promotes critical and reflective thinking among audiences, which aligns with constructivist principles and facilitates social presence.

Simulation-based learning. The workshop section is designed with pragmatism in manner. To achieve pragmatism, a simulation-based learning method is integrated in this section. Specifically, audiences are given hands-on experiences in developing a simplified version of a DApp, based on a real-world setting. It bridges the knowledge, which is conveyed in seminar, and the skill of application development using blockchain technology.

3.3 Content and schedule

In our framework, the curriculum is organized in 3 days. In our implementation, the 7.5-hours seminar introduces fundamental blockchain ideas, which focus on theoretical aspects of blockchain. The 15-hours workshop introduces a practical use case which is to build up a blockchain-based anti-counterfeiting system using Hyperledger Fabric (Androulaki et al., 2018; Performance & Group, 2018). Hyperledger Fabric is adopted as the blockchain framework because it is decoupled from the traditional cryptocurrency paradigm, which helps clarify that cryptocurrency is not the only application of blockchain, and blockchain can be used to build up IT applications without having any cryptocurrency. Since the audiences are mostly IT practitioners who are more interested in applying the technologies in their workplace. So a blockchain framework that can be adopted in an enterprise setting is preferred. In addition, participation in the workshop section is optional. The framework schedule is shown in Table 3.

3.3.1 Day 1 – seminar

Seminar audiences are provided with an introduction to fundamental blockchain knowledge, including history, characteristics, and structure. Key technologies are introduced as well, including digital signature, hash functions and merkle tree. The related concepts, terminology, security properties, issues, and limitations are conveyed to audiences as well. The second part introduces major blockchain frameworks for application development to audiences, including Ethereum, Hyperledger Fabric, Corda and other newly emerging frameworks. Several models for assessing the feasibility of adopting blockchain technology in IT projects are explored afterwards. A practical use case is adopted to illustrate the assessment to help audiences understand the process. Finally, audiences have to form groups, and they are given various potential use cases, which include applications in different industry sectors, to assess the feasibility of blockchain adoption based on introduced models.

3.3.2 Day 2 – workshop

Audiences are introduced to a basic background of Hyperledger Fabric framework. Several major components and their relationship among a Hyperledger Fabric network, such as Peer, Orderer, and Membership Service Provider (MSP), are introduced. Then,

Table 3 Schedule of the training framework

Section	Duration	Activity
Seminar(Day 1)	2 hours	Overview of Latest Blockchain Development
	2 hours	Major Blockchain Solutions/Frameworks for Application Development
	2 hours	Case Studies of Blockchain Application from Private and Public Sectors
	30 mins	Group Discussion on Potential Applications/Projects that can make use of Blockchain
	30 mins	Group Presentation
	30 mins	Introduction of Potential Blockchain-based Projects
Workshop(Day 2)	2 hours	Background of Hyperledger Fabric
	1.5 hours	Hands-on Exercises (1): Experiencing a Practical Blockchain-based Application
	4 hours	Hands-on Exercises (2): Implementing Chaincode for Data Transactions and Queries
Workshop(Day 3)	3.5 hours	Hands-on Exercises (3): Building up a Web-based Front-end for the Application
	3.5 hours	Hands-on Exercises (4): Configuring Hyperledger Fabric network
	30 mins	Sharing of Best Practices and Common Pitfalls of Blockchain-based Applications
After Training	-	Extracurricular Exercises: Further Reading
	-	Badge Rewarding

audiences are introduced to the transaction flow and life cycle in Hyperledger Fabric. It is followed by an introduction of a practical application, which is an anti-counterfeiting system. Then, audiences will be given a Ubuntu Linux OS environment to complete the implementation of an anti-counterfeiting system. The OS environment is pre-packaged in terms of a virtual machine image, which can be easily deployed in various host machines. A workshop manual is provided to audiences with the trainer's guidance. Audiences are required to complete the tasks in terms of calling sample shell scripts and javascript and implementing incomplete chaincode functions.

3.3.3 Day 3 – workshop

Audiences are required to complete the implementation of an anti-counterfeiting system by integrating a Web-based front end. By building up a blockchain application with a user interface that resembles commonly used "apps", audiences would better grasp the architecture and flow of developing blockchain applications. Also, audiences are required to perform basic configuration of Hyperledger Fabric network and observe transaction behaviors and outcomes through a Web-based blockchain explorer.

After audiences have completed the tasks of implementing the anti-counterfeiting system and blockchain network configuration, the trainer will then introduce the design patterns and security considerations in blockchain application development, as well as the new trends of blockchain frameworks.

3.3.4 After training

After attending the seminar, participants are encouraged to explore more about the technology and its use case by reviewing a recommended online edx course (https://www.edx.org/course/understanding-blockchain-and-its-implications) at home. After completing a quiz of 15 MCQs, they will receive a blockchain-based digital badge, which certifies the completion of the training. A custom system is made to generate the digital badge which comprises a certificate image file and a proof file in JSON format. The proof file is generated after the image file metadata is successfully uploaded to the Bitcoin network. Participants who earn the badge will receive an image and a proof file, which can be verified via our verification system (Fig. 2). This badge generation and verification system exemplifies a real-world blockchain application. Through self-study and experience with the blockchain-based digital badge system, participants are able to gain an enhanced understanding of the intricacies underlying blockchain technology.

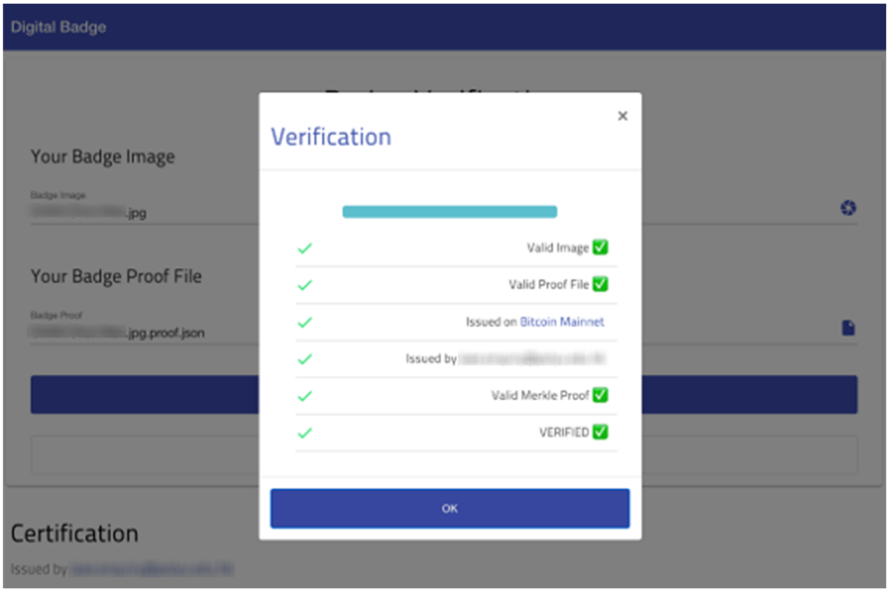

Fig. 2 Verification interface of digital badge system

3.4 Target audiences

This training framework is designed particularly for IT practitioners who have some technical computing background but are not familiar with blockchain. They may need to have themselves prepared to adopt blockchain in their workplace and in the IT systems that they are developing, managing, and operating. Therefore, our framework is designed in a way that, on the one hand, the concepts, theories, and use cases are introduced; on the other hand, hands-on tasks for system setup and development provide a taste and a more concrete feeling to audiences about blockchain technology and application.

4 Research method and results

4.1 Method

Table 4 provides an overview of the research and analysis methods adopted in this research. Mixed methods, which include pre- and post-questionnaires and knowledge quizzes, are adopted in this study.

The knowledge quizzes are used to examine the level of blockchain technology understanding among audiences and the effectiveness of seminar. Then, there is a pre-quiz before seminar and a post-quiz after seminar. For pre-quiz and post-quiz, there are ten MCQ questions that cover beginner-to-intermediate level questions pertaining to concepts, theories, and properties of blockchain. In addition, a paired samples t-test was applied to examine the results of both the pre-quiz and post-quiz. This parametric test was selected as it enables the evaluation of academic performance changes that occurred within the same group of participants both before and after the workshop, as opposed to comparing different groups of students. The participant results from the quizzes will be utilized as a sample if and only if the participant completes both the pre-quiz and post-quiz.

The pre- and post-questionnaires collect audiences' expectations, satisfaction levels, and feedback about the training framework. Three sets of feedback questionnaires are designed: (1) a pre-questionnaire for training, (2) a post-questionnaire for seminar, and (3) a post-questionnaire for workshop. The pre-questionnaire for training adopts four open-ended questions to seek participants' expectations. This questionnaire is distributed before participants attend the training (i.e., before attending seminar or workshop section). The post-questionnaires for seminar and workshop adopt five-point Likert scale and open-ended questions. These questionnaires are designed in a manner to elicit feedback on the training and are distributed after seminar and workshop.

To implement the analysis methods, a paired sample t-test and descriptive statistics are performed to analyze the data collected from feedback questionnaires and knowledge quizzes using IBM SPSS software Statistics. In addition, the pre-questionnaires applied the Latent Dirichlet Allocation (LDA) method to conduct text mining and topic modelling to investigate the participants' expectations, which is the approach that is workable for analyzing the responses from open-ended questions (Buenano-

Table 4 Overview of research and analysis methods

Method	Type		Analysis Method(s)	Assessment for RQ		
	Qualitative	Quantitative		i	ii	iii
Pre-questionnaire	✓		- Descriptive statistics - Text mining - Topic modeling		✓	
Knowledge quizzes		✓	- Descriptive statistics - Comparative statistics			
Post-questionnaire (Seminar)	✓	✓	- Descriptive statistics - Text mining	✓	✓	✓
Post-questionnaire (Workshop)	✓	✓	- Descriptive statistics - Aspect-based sentiment analysis	✓	✓	✓

Fernandez et al., 2020; Nanda et al., 2021). Furthermore, the open-ended questions in post-questionnaires were analyzed using MonkeyLearn, a text analysis application with acceptable accuracy in sentiment analysis (Sadriu et al., 2021). It is utilized to generate a report using aspect-based sentiment analysis to determine participants' sentiments towards the training contents and delivery. The subsequent section will give more details on the procedures for analyzing the responses to open-ended questions.

4.1.1 Response Analysis Techniques

Prior to analysis, the data collected performed cleaning processes to ensure its accuracy and quality before being fed into the algorithm or software. The processes encompassed data validation, enrichment, and classification, resulting in the refined data being organized as a collection of documents (Fig. 3), each including all of the responses for a single question.

Initially, the textual data (i.e., responses to open-ended questions) were gathered and subsequently organized into an Excel spreadsheet for storage. Each row in the spreadsheet represents a single record.

Next, it conducted a uniqueness check to remove or combine the duplicated data, utilizing the email address as the primary key. After that, correct the inaccurate responses to facilitate the accuracy of response analysis. For example, if the response "same as above" occurs, it will be linked to the participants' previous responses, then replace the current response with the previous one to correct the data. The response containing undefined symbols will also be corrected.

Subsequently, each row of responses undertook a classification process to determine if they were substantial or non-substantive. In this study, non-substantive responses were defined as irrelevant noise in text analysis, while the performance of data analysis can be enhanced by removing the noise (Xiong et al., 2006). The non-substantive responses included "N/A", "Nil", "-", "/", "No idea", and "I don't know", and the responses unable to answer the question classified as "non-substantive with justification", such as "No related experience", "Not sure since not understand what Blockchain exact is", and "Can't find it yet". Furthermore, non-substantive responses were used to produce a frequency distribution, distinct from the substantial responses, as the non-substantive responses have statistical significance in capturing participants' uncertainty or inability to provide a response (Young, 2012; Gehlbach, 2015).

Eventually, the substantive response was used to create a collection of documents. A document included all the substantial responses for a single question. The collection of documents consisted of four documents for the pre-questionnaire, two for the seminar post-questionnaire, and two for the workshop post-questionnaire. Every row in the documents corresponds to one participant's response to one question.

Fig. 3 Flow of data cleaning

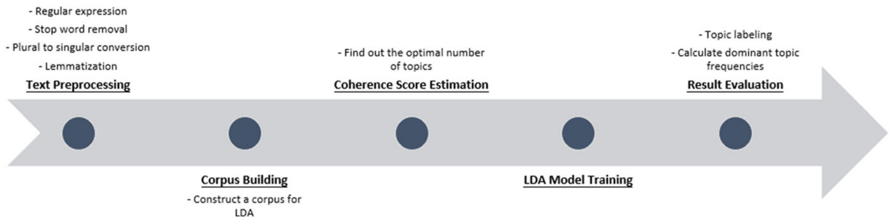

Fig. 4 Flow of text mining and topic modelling by applying LDA

The pre-questionnaire documents were used to conduct text mining and topic modelling by applying LDA. The text mining and topic modelling process consisted of five parts: text preprocessing, corpus building, coherence score estimation, LDA model training and result evaluation (Fig. 4). In addition, Python was utilized as the language for implementing a program that carried out the processes, employing Gensim as the imported library for realizing the LDA.

The program originally parsed a document to extract its content as a dataset. Afterwards, text preprocessing was performed to adjust the data in preparation for training the LDA model. The text preprocessing involved regular expression, stop word removal, plural to singular conversion, and lemmatization. After that, construct a corpus using the processed data. Next, perform a coherence score estimation test to determine the most optimal number of topics ranging from two to fifteen. Following that, assign the most optimal number as a parameter for executing LDA model training. Ultimately, the results of the training will then be employed to figure out the frequencies of the dominant topic and implement topic labelling. Topic labelling was performed based on the tokens in the cluster to determine the label manually.

Besides, the seminar and workshop post-questionnaire documents were imported into MonkeyLearn to generate an aspect-based sentiment analysis report. To enhance the report's accuracy, the data labels were manually checked. The label will be updated if the data label is not accurate.

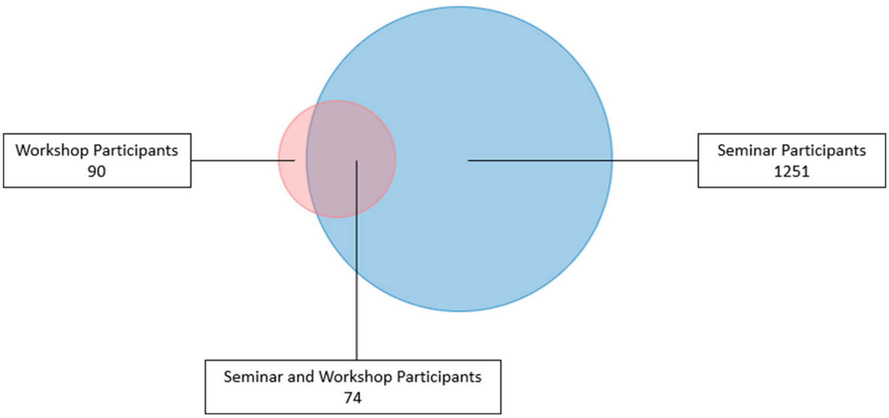

Fig. 5 Venn diagram for presenting the number of participants

Table 5 Classification and distribution of participants' department

Related Field	Number	Percent	Department(s)	
Building and Environmental	117	9.2	- Agriculture, Fisheries and Conservation Department	- Highways Department
			- Architectural Services Department	- Housing Department
			- Buildings Department	- Land Registry
			- Civil Engineering and Development Department	- Lands Department
			- Environmental Protection Department	- Planning Department
Disciplined Services	241	19.0	- Civil Aid Service	- Immigration Department
			- Correctional Services Department	- Marine Department
			- Customs and Excise Department	- Police Force
			- Fire Services Department	- Security Bureau
			- Government Flying Service	
Economic and Finance	182	14.4	- Commerce and Economic Development Bureau	- Official Receiver's Office
			- Commerce, Industry and Tourism Branch	- Secretariat, University Grants Committee
			- Companies Registry	- Student Finance Office
			- Financial Services and the Treasury Bureau	- The Treasury
			- Government Logistics Department	- Trade and Industry Department
			- Inland Revenue Department	- Working Family Allowance Office
			- Invest	- Working Family and Student Financial Assistance Agency
			- Office of Commissioner of Rating and Valuation	
Educational	34	2.7	- Education Bureau	
Engineering and Science	25	2.0	- Electrical and Mechanical Services Department	- Observatory
			- Innovation and Technology Bureau	

Table 5 continued

Related Field	Number	Percent	Department(s)	
General Affair	401	31.6	- Census and Statistics Department	- Information Services Department
			- Chief Secretary for Administration's Office	- Office of the Government Chief Information Officer
			- Civil Service Bureau	- Registration and Electoral Office
			- Constitutional and Mainland Affairs Bureau	
Healthy	61	4.8	- Department of Health	- Food and Health Bureau
			- Food and Environmental Hygiene Department	
Law	50	3.9	- Department of Justice	- Legal Aid Department
			- Judiciary	
Social	156	12.3	- Development Bureau	- Leisure and Cultural Services Department
			- Drainage Service Department	- Planning and Lands Branch
			- Home Affairs Bureau	- Post Office
			- Home Affairs Department	- Social Welfare Department
			- Intellectual Property Department	- Transport Department
			- Labour Department	- Transport and Housing Bureau
			- Labour and Welfare Bureau	- Water Supplies Department

Table 6 Questions of pre-questionnaire

Question ID	Question
Q1	What are your expectations of this training course?
Q2	What new initiatives/challenges/issues/ problems you are currently facing at work that may be solved by Blockchain technology?
Q3	What are the challenges that you foresee you may encounter when you adopt Blockchain technology at work?
Q4	What questions/ issues/ topics about Blockchain that you would like the speakers to address in the workshop?

4.2 Results

4.2.1 Demographic

The framework was adopted in a series of training for IT officers of a government in 2019–2021, with the objective of increasing literacy of blockchain technology among them. 1,251 officers attended seminar while 90 officers attended workshop, while 74 officers attended both seminar and workshop (Fig. 5). The IT officers involved in the training are stationed in 65 functional departments, which can be categorized into 9 professional fields (Table 5).

4.2.2 Expectations from participants

A pre-questionnaire for eliciting the expectations was distributed to participants before they attended training. There are totally four open-ended questions (Table 6). The results of data cleansing are presented in Table 7. Besides, the text mining and topic modelling results are presented in Table 8. A topic comprises numerous tokens, and seven representative tokens are selected to present in the table. There are 343 responses for the pre-questionnaire.

The Q1 results indicated that participants expect to learn blockchain in four aspects: competence, application, evaluation, and functionality. For the aspect of competence, the participants expect to gain the concepts, knowledge, skills, and principles of

Table 7 Data cleansing results of pre-questionnaire

Question ID	Number of Responses		
	substantive	non-substantive	non-substantive with justification
Q1	340	3	0
Q2	113	173	57
Q3	240	88	15
Q4	340	94	0

Table 8 Text mining and topic modeling results of pre-questionnaire

Question ID	Coherence Score	Perplexity	Topic ID	Label	Representative Tokens	% of tokens	Dominant Topic Count
Q1	0.4296	-5.7984	Q1-T1	Concept of Application	principle, capability, solution, requirement, appliance, suitable, general	15.8	71
			Q1-T2	Knowledge and Skills	basic, concept, understand, knowledge, datum, skill, theory	15.2	58
			Q1-T3	Consideration in Practical Application	practical, case, clear, con, pro, plan, concise	11.9	50
			Q1-T4	Common Usage	use, apply, business, applicable, opportunity, operation, daily	11.4	42
			Q1-T5	Market and Workplace	market, work, agile, computation, cryptocurrency, fintech, city	10.2	34
			Q1-T6	Technical	technical, environment, estimation, cost, terminology, feasibility, transaction	9.6	29
			Q1-T7	Insight and Restrictions on Public	insight, major, limitation, public, update, sector, service	9.5	18
			Q1-T8	Sustainability	trend, future, expect, benefit, time, mechanism, resource	6.7	16
			Q1-T9	Community	well, society, acquaintance, job, discussion, gov, private	5.1	12
			Q1-T10	Security and Privacy	verification, privacy, personal, authentication, issue, information, security	4.7	10
Q2	0.5063	-6.6251	Q2-T1	Data Management	record, register, procurement, keep, copy, store, streamline	19.7	24
			Q2-T2	Security	security, transaction, trace, problem, issue, handle, cargo	19	21

Table 8 continued

Question ID	Coherence Score	Perplexity	Topic ID	Label	Representative Tokens	% of tokens	Dominant Topic Count
			Q2-T3	Authentication	username, password, adjustment, alternation, checksum, country, management	14.8	17
			Q2-T4	Identification	update, exchange, delivery, trade, identity, record, verification	14.3	16
			Q2-T5	Data Privacy	news, personal, sensitive, unauthorized, distribute, ledger, membership	12	12
			Q2-T6	Reliability	event, possible, medium, critical, reliability, construction, software	10.9	12
			Q2-T7	Insufficient Understanding	support, upcoming, new, knowledge, technical, lack, infrastructure	9.4	11
Q3	0.5229	-6.8674	Q3-T1	Security and Privacy	security, implementation, difficult, resistance, privacy, sensitive, management	25.5	67
			Q3-T2	Functionality	storage, public, transaction, amendment, rectify, licence, networkfirewall	16	46
			Q3-T3	Configuration and Implementation	resource, requirement, measure, suitable, migration, contractor, perception	15.1	41
			Q3-T4	Market Value	experience, lack, market, familiar, solution, effectiveness, availability	15.1	30
			Q3-T5	Production Development	application, product, real, limitation, quality, software, misconception	14.9	29
			Q3-T6	Technology Adoption and Manpower Development	project, procedure, vendor, manpower, specialist, adoption, environment	13.4	27

Table 8 continued

Question ID	Coherence Score	Perplexity	Topic ID	Label	Representative Tokens	% of tokens	Dominant Topic Count
Q4	0.5131	-6.5474	Q4-T1	Adoption in Government Situations	government, application, adopt, apply, implementation, concern, determine	32.8	91
			Q4-T2	Cryptocurrency and Business	real, cryptocurrency, usage, trend, business, fundamental, organization	20.4	57
			Q4-T3	Implementation in Technical Aspect	problem, encounter, database, maintenance, environment, efficiency, resolve	20	46
			Q4-T4	Pros and Cons	record, possible, limitation, weakness, require, advantage, contradiction	15.4	31
			Q4-T5	Teaching Style	development, practical, useful, valuable, demo, fact, software	11.3	24

blockchain, which is the primary aspect they have high expectations for. This can be proved by the percentage of tokens and high dominant topic count. Participants also expect to learn the application of blockchain. Specifically, they expect to learn the practical usage of blockchain and the considerations when adopting it. For the evaluation aspect, participants expect to understand the value, pros and cons, impact on the community, and limitations of blockchain. Lastly, the participants expect to learn about the functionality of blockchain such as sustainability, security, and privacy management.

Regarding the Q2 results, participants expect that blockchain technology can address difficulties associated with data management, security, authentication, identity, data privacy, and dependability. Nevertheless, the results also revealed that most participants lack insufficient blockchain understanding. A total of 173 replies were deemed non-substantive. Except for these, 57 participants explicitly stated they did not have relevant experience and knowledge. The non-substantive responses accounted for 67% of the responses received to this question. Insufficient understanding also emerged as a recurring topic in text mining and topic modelling results.

The Q3 results revealed the potential challenges that participants may encounter when adopting blockchain technology. These challenges are classified into six categories: security and privacy, functionality, configuration and implementation, market value, production development, as well as technology adoption and manpower development. The participants expressed significant apprehension over the security and privacy concerns, while the analysis of text mining and topic modelling showed that security and privacy constituted the topic containing the largest proportion.

The Q4 results indicate that participants expect the trainer to cover several aspects, including adoption in government situations, cryptocurrency and business, implementation in technical aspects, as well as advantages and disadvantages. The majority of participants exhibit a preference for obtaining information on the topic of adoption within governmental contexts. Specifically, their primary interest is determining the appropriate timing to adopt blockchain technology, particularly within government operations. This could be demonstrated by the presence of 32.8% tokens and a count of 91 dominating topics in this particular topic. Furthermore, a small portion of participants responded to the teaching style. They expect the trainer to provide more practical, useful, and valuable examples to demonstrate blockchain.

4.2.3 Effectiveness

948 participants (N = 948) responded to the pre- and post-quizzes. Each MCQ weighs 1 mark and the full mark is 10. The results of the quizzes are summarized in Table 9 and Fig. 6.

The mean score improved by 2.28 (from 3.53 in pre-quiz to 5.81 in post-quiz), and the t-test significant value is 0.000, which indicated that seminar significantly enhanced audiences' knowledge about blockchain technology. In this framework, seminar plays a crucial role in strengthening the fundamental knowledge among audiences. Also, it establishes the essential groundwork for taking part in workshops and pursuing advanced blockchain concepts in the future.

Table 9 Statistics of pre-test, post-test, and paired samples t-test

	Pre-Test Marks	Post-Test Marks	Paired Samples T-Test (Pre-Test Marks & Post-Test Marks)
Mean	3.53	5.81	2.27
Std. Deviation	1.65	2.19	2.37
Std. Error Mean	0.54	0.71	0.77
t	N/A	N/A	29.603
df	N/A	N/A	947
Sig. (2-tailed)	N/A	N/A	0.000

4.2.4 Feedback

The post-questionnaire consists of 16 questions (Table 10). The questions for both seminar and workshop are the same. Q1 to Q14 are five-point Likert scale questions, while Q15 and Q16 are open-ended questions for written feedback and suggestions. Q1 to Q3 are used to assess the course design and content quality. Q4 and Q5 are used to assess the quality of handouts and reference materials. Q6 to Q9 are the questions for measuring whether the training can fulfil the learning outcomes. Q10 to Q14 require participants to provide an overall rating in different aspects of training. Q15 collects their other comments on training. Q16 elicits the topics that participants would like to add to the training.

Seminar Table 11 summarizes the responses from seminar participants for Q1 to Q14.

The results of Q1 to Q3 indicated that most of the respondents were satisfied with the course design and contents of seminar. For Q1, over 90% respondents rated satisfied or strongly satisfied, indicating that respondents agreed that the seminar contents were

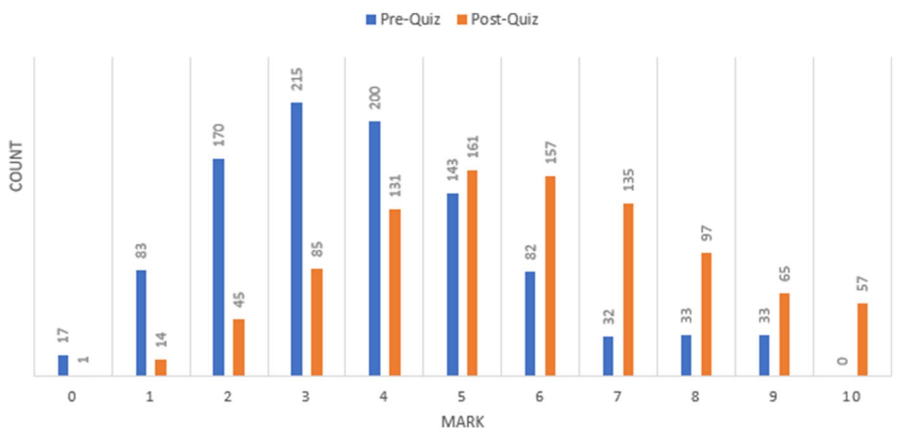

Fig. 6 Column chart of pre-test and post-test results

Table 10 Questions of post-questionnaire

Question ID	Question
Q1	Please rate the usefulness of the course contents.
Q2	Please rate the duration of the course.
Q3	Please overall rate the content.
Q4	Please rate the level of standard for the handouts and reference materials.
Q5	Please rate the level of detail for the handouts and reference materials.
Q6	Please rate whether the course is relevant to your needs.
Q7	Please rate whether the course is enhancing your knowledge in the subject.
Q8	Please rate whether the course applies what you have learned in your work.
Q9	Please rate whether the course matches the training objectives.
Q10	Please overall rate the satisfaction with the teaching quality.
Q11	Please overall rate the satisfaction with your learning experience.
Q12	Please overall rate the gains in your learning/development.
Q13	Please overall rate to what extent the training meets your expectations.
Q14	Please overall rate the assessment of the course.
Q15	Please give general comment on the training course.
Q16	What other topics should be included?

Table 11 Seminar post-questionnaire results (Q1 to Q14)

Question ID	Response Count	Strongly Dissatisfied	Dissatisfied	Neutral	Satisfied	Strongly Satisfied
Q1	1115	0	0	93	580	442
		0.000	0.000	0.083	0.519	0.395
Q2	1115	1	31	221	579	283
		0.001	0.028	0.198	0.518	0.253
Q3	1115	0	1	96	648	370
		0.000	0.001	0.086	0.580	0.331
Q4	1113	1	5	102	640	365
		0.001	0.004	0.092	0.575	0.328
Q5	1112	0	8	113	623	368
		0.000	0.007	0.101	0.560	0.331
Q6	1114	7	46	311	545	205
		0.006	0.041	0.279	0.489	0.184
Q7	1114	0	4	120	574	416
		0.000	0.004	0.108	0.515	0.373
Q8	1113	24	88	499	374	128
		0.021	0.079	0.448	0.336	0.115
Q9	1112	1	1	96	600	414
		0.001	0.001	0.086	0.540	0.372

Table 11 continued

Question ID	Response Count	Strongly Dissatisfied	Dissatisfied	Neutral	Satisfied	Strongly Satisfied
Q10	1116	1	1	65	642	407
		0.001	0.001	0.058	0.575	0.365
Q11	1116	0	4	85	671	356
		0.000	0.004	0.076	0.601	0.319
Q12	1116	0	6	136	651	323
		0.000	0.005	0.122	0.584	0.289
Q13	1114	0	6	124	646	338
		0.000	0.005	0.111	0.581	0.303
Q14	1114	0	3	78	679	354
		0.000	0.003	0.070	0.610	0.317

useful. Over 75% respondents were well-pleased with the duration of seminar, and around 2.9% respondents were dissatisfied with Q2. The overall rating of seminar design and contents was reflected by the fact that 91.1% respondents rated satisfied or strongly satisfied in Q3. The result of Q4 and Q5 indicated that participants were satisfied with the quality of seminar handouts and reference materials. There were 90.3% respondents rated satisfied or strongly satisfied for Q4, while there are 89.1% rated satisfied or strongly satisfied for Q5.

In general, the results of Q6 to Q9 indicated that seminar could fulfil the learning objectives. There were nearly 90% of the respondents rating satisfied or strongly satisfied for Q7 and Q9. The results of Q6 and Q8 were slightly inferior. Nearly 67% participants rated satisfied or strongly satisfied for Q6, while there are 4.1% respondents rated dissatisfied, and 0.6% respondents rated strongly dissatisfied. The result of Q6 indicated that seminar was relevant to the needs of over half of the respondents but not suitable for a small portion of the respondents. Besides, the result of Q8 indicated that the knowledge learned from seminar may not be relevant to the workplace.

All in all, the respondents were satisfied with seminar, and this can be well-proven by the results of Q10 to Q14. There were nearly 90% participants rated satisfied or strongly satisfied with the teaching quality, their learning experience, the gains in the learning process, and alignment with their expectations. Specifically, 94% respondents rated satisfied or strongly satisfied with the teaching quality, 92% rated satisfied or strongly satisfied with their learning experience, 87.3% rated satisfied or strongly satisfied with the gains in their learning process, 88.4% rated satisfied or strongly satisfied about alignment to their expectations, and 92.7% rated satisfied or strongly satisfied in the overall assessment of seminar.

105 participants responded to Q15. For the sentiment analytic result for Q15 (Fig. 7), there are 53.3% respondents provided positive responses, 20.5% neutral responses, and 26.2% negative responses. Specifically, most of the positive responses commented that seminar was clear, great, interesting, and good for blockchain beginners. Some of the respondents commented that the trainers were friendly, knowledgeable, and had good content and presentation. On the other hand, most of the negative responses commented that the duration of seminar was too packed and there was too much content. Besides, several participants commented that seminar contents were not easy.

There are 34 responses for Q16. The result of Q16 (Table 12) indicated that most of the respondents would like to have more case studies to help their understanding, concepts and mechanisms of blockchain. They also would like to know how blockchain

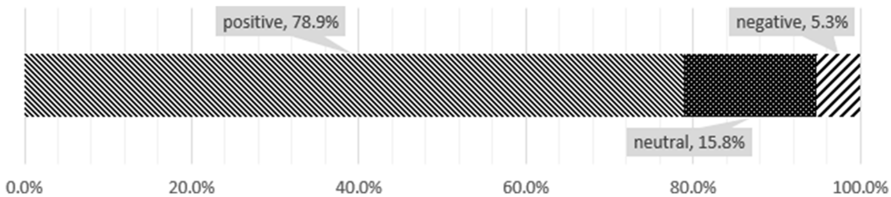

Fig. 7 Sentiment analytic result of question 15 in seminar post-questionnaire

Table 12 Aspect count of Q16 responses in seminar post-questionnaire

Aspect	Frequency
Case Study	22
Application	13
Scalability	6
Basic Concept	4
Course Design	3
Cryptocurrency	2

technology can be applied in various sectors and other considerations, including scalability, design, and architecture.

Workshop Table 13 summarizes the responses of Q1 to Q14.

The results of Q1 to Q3 indicated that most of the respondents were satisfied with course design and contents. There were 94% respondents rating satisfied or strongly satisfied for Q1, while there were 89.1% respondents rating satisfied or strongly satisfied for Q2. For the overall rating question Q3, there were 95% respondents expressed that they were satisfied or strongly satisfied with workshop design and contents. Moreover, the results of Q4 and Q5 indicated that the quality of handouts and reference materials was high. 92.9% respondents rated satisfied or strongly satisfied for Q4, and 91% participants rated satisfied or strongly satisfied for Q5. In addition, it is worth highlighting that there were none of the respondents rated dissatisfied and strongly dissatisfied for Q1 to Q5, which indicated that the quality of workshop design, contents, handouts, and reference materials is high.

The results of Q6 to Q9 indicated that workshop fulfilled the learning objectives. 96% and 91.1% respondents rated satisfied or strongly satisfied, respectively for Q7 and Q9, while nearly 70% respondents rated satisfied or strongly satisfied for Q6 and Q8.

The results of Q10 to Q14 indicated that most of the participants were satisfied. There were more than 90% respondents rated satisfied or strongly satisfied for Q10 to Q14. 96.1% respondents rated satisfied or strongly satisfied for Q10, 94.1% for Q11, 93.1% for Q12, 90.2% for Q13, and 95.2% for Q14.

90 participants responded to Q15. The sentiment analytic result for Q15 (Fig. 8) indicated that the respondents had positive feelings about workshop. There were 78.9% respondents who provided positive responses, 15.8% neutral responses, and 5.3% negative responses. Specifically, most of the positive responses commented that workshop was good and great, specifically in the T&L process of programming and developing a DApp, and also stated that it is suitable for beginners. Oppositely, a few participants commented that 2-days (i.e., 15 contact hours) arrangement was too packed and suggested that learning materials should be available before workshop.

There are 12 responses received for Q16. The analytic result of Q16 (Table 14) was similar to the result of seminar questionnaire Q16. Most of the respondents would like to have more case studies. Also, the respondents would like to add some content related to cryptocurrency. Indeed, we also incorporated the topics of proof-of-stack

Table 13 Workshop post-questionnaire results (Q1 to Q14)

Question ID	Response Count	Strongly Dissatisfied	Dissatisfied	Neutral	Satisfied	Strongly Satisfied
Q1	101	0	0	6	49	46
		0.000	0.000	0.059	0.485	0.455
Q2	101	0	0	11	48	42
		0.000	0.000	0.109	0.475	0.416
Q3	101	0	0	5	50	46
		0.000	0.000	0.005	0.455	0.495
Q4	99	0	0	7	43	49
		0.000	0.000	0.071	0.434	0.495
Q5	99	0	0	9	45	45
		0.000	0.000	0.091	0.455	0.455
Q6	101	0	1	23	47	30
		0.000	0.010	0.228	0.465	0.297
Q7	101	0	0	4	46	51
		0.000	0.000	0.040	0.455	0.505
Q8	101	1	2	32	46	20
		0.010	0.020	0.317	0.455	0.198
Q9	101	0	0	9	43	49
		0.000	0.000	0.089	0.426	0.485
Q10	102	0	0	4	45	53
		0.000	0.000	0.039	0.441	0.520

Table 13 continued

Question ID	Response Count	Strongly Dissatisfied	Dissatisfied	Neutral	Satisfied	Strongly Satisfied
Q11	102	0	0	6	45	51
		0.000	0.000	0.059	0.441	0.500
Q12	102	0	0	7	48	47
		0.000	0.000	0.069	0.471	0.461
Q13	102	0	0	10	45	47
		0.000	0.000	0.098	0.441	0.461
Q14	102	0	0	5	47	50
		0.000	0.000	0.049	0.461	0.490

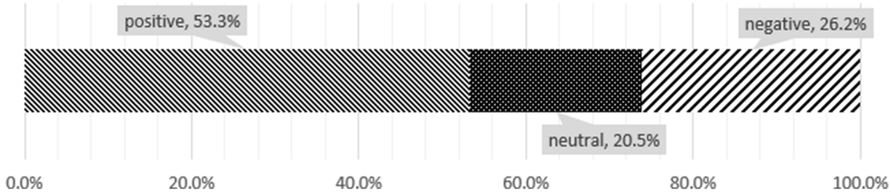

Fig. 8 Sentiment analytic result of question 15 in workshop post-questionnaire

migration of Ethereum and its impact. We realized that a number of participants showed particular interest in the rewarding mechanism of cryptocurrency. Moreover, some of the respondents suggested incorporating more hands-on tasks related to blockchain network configuration and restoration.

5 Discussion

5.1 Effectiveness of the framework

Our training framework aims to facilitate the T&L process in blockchain education. The target audience is IT practitioners with computing backgrounds but unfamiliar with blockchain technology. Our approach is proven to be successful for blockchain beginners to have a taste in terms of theories, use cases, and basic application implementation and configuration.

Eventually, the evaluation results showed that the framework was effective in achieving the learning objectives and accomplishing the goal of facilitating the T&L process. The comparison of the pre- and post-quizzes in seminar indicated that the participants enhanced their awareness and knowledge of blockchain significantly (p-value < 0.000). Besides, the quantitative and qualitative responses from seminar and workshop post-questionnaire (Q1 to Q15) showed that the respondents were mostly satisfied, while these satisfaction levels can be used as indicators to prove the training framework is effective. Several studies indicated that satisfaction has been extensively employed to measure learning effectiveness in educational studies, and a positive

Table 14 Aspect count of Q16 responses in workshop post-questionnaire

Aspect	Frequency
Case Study	8
Application	4
Cryptocurrency	3
Configuration	2
Restoration	1
Scalability	1

relationship exists (Alavi et al., 1995; Chou & Liu, 2005; Ye et al., 2022; Wei et al., 2022). In addition, positive relationships can be demonstrated in technology-related subjects (Abd Rahman et al., 2019; Han et al., 2021; Elhadary, 2016).

Furthermore, meeting learners' expectations is fundamental to achieving effectiveness in this training framework. A number of studies have already explored the relationship between student expectations, performance, and satisfaction by employing the Expectancy-Disconfirmation Model (Tomlinson et al., 2023; Appleton-Knapp & Krentler, 2006). According to the model, when there are discrepancies between what students expect and what really happens, they may get negative disconfirmation (i.e., dissatisfaction) (Tomlinson et al., 2023; Byrne et al., 2012; Lowe & Cook, 2003; Money et al., 2017). This disconfirmation can have a detrimental effect on their level of engagement, academic performance, and retention (Brookover et al., 1982; Vinson et al., 2010; Bordia et al., 2006). In this study, our framework is tailored and designed to meet the target learners' (i.e., IT practitioners) expectations. For instance, the architecture, usage, and value of blockchain were explained by citing several international blockchain applications used by industries and governments to fulfil participants' expectations in learning blockchain competence, application, evaluation, and functionality (pre-questionnaire Q1). Also, by simulating possible scenarios in government departments in the case study activity, learners are prompted to consider the decision of whether or not to adopt blockchain technology to fulfil participants' expectations on the topic of adoption within governmental contexts (pre-questionnaire Q4). The fulfilment of learners' expectations enhances their performance (pre- and post-quizzes) and decreases their dissatisfaction (post-questionnaire), eventually achieving effectiveness.

Nevertheless, there is an interesting observation from the results of Q6 and Q8 from seminar post-questionnaires. A few respondents commented that blockchain technology was irrelevant to their needs and would not apply it in their workplace. We interpreted that as good responses. Blockchain is a technology that may not be suitable in certain real-life scenarios due to the tradeoffs and limitations of the technology, e.g., performance and cost of implementation and setup, and security. So, we concluded that the participants were able to grasp the concepts of technology properly after attending seminar and thus able to make the correct responses.

In addition, our framework provides flexibility. Our framework allows modularization of the contents, i.e., the theories and case studies part (i.e., seminar) and the hands-on experience part (i.e., workshop). It was designed generically in the sense that it is not tightly coupled to particular vendor framework(s) or software tools. For example, we introduced Ethereum, Hyperledger Fabric, and Corda in seminar and adopted Hyperledger Fabric in workshop on our framework implementation. Adopters of our framework can freely introduce other blockchain frameworks based on the trainers' preferences, technology familiarity, as well as the trends of the industry.

5.2 Effectiveness of using constructivist and pragmatic approach

The integration of constructivism and pragmatism can mutually enhance their effectiveness. A study provided the results before and after treatment of implementing constructivist teaching, which showed that constructivist teaching does not have any influence on learners' self-concepts and may have a detrimental effect on their motivation to learn (Kim, 2005). Nevertheless, there is a strong correlation between learners' self-concepts and accomplishment in specific domains (McInerney et al., 2012; Marsh & Craven, 2006; Seaton et al., 2010), and motivation serve as a factor in influencing learning effectiveness (Zaccone & Pedrini, 2019; Huang & Yang, 2021; Atma et al., 2021). Based on this viewpoint, the constructivist teaching approach may have a hidden worry in developing learners' self-concepts and motivation, which may eventually affect the effectiveness of learning. On the other hand, pragmatic teaching approaches can bring self-concepts (Betz et al., 2021; Mihindo & Kamonjo, 2022) and motivation (Lin et al., 2018; Horntvedt et al., 2018; Negro et al., 2019; Otto, 2014) to the learners, while this can make up for the weakness of constructivist teaching. However, a pragmatic teaching approach may yield dissatisfied results in cultivating learners' knowledge generalization (Mekonnen, 2020), which refers to the ability to apply knowledge in new situations (Gluck et al., 2008). In this regard, constructivist teaching approaches can effectively foster learners' capacity for knowledge generalization (Selçuk & Yilmaz, 2020; Laz & Shafei, 2014), compensating for the drawbacks of the pragmatic teaching approach.

The results indicate that constructivism and pragmatism can complement each other. Our training course utilizes problem-based learning method for implementing constructivism and problem-based learning for implementing pragmatism, which can significantly enhance the learning outcomes. In the constructivist section (i.e., seminar), students applied the knowledge in group-based case studies, discussions and presentations. Through those processes, the trainees constructed their own perspectives on blockchain technology. Eventually, they could determine under what circumstances a problem can be solved by applying blockchain technology, as well as construct their own understanding on the knowledge of blockchain. This can be supported by the results of seminar post-questionnaire Q6 and Q8. While in the pragmatic section (i.e., workshop), the students eventually enhanced their practical skills by developing blockchain-based applications Similarly, the effectiveness can be proven by the workshop post-questionnaire results.

The training framework provided versatile outcomes based on constructivism and pragmatism. While the seminar successfully activated the participants' critical thinking and problem-solving abilities in blockchain technology, it had limitations in helping the trainees understand the technical aspects of the technology. Therefore, a pragmatic approach complements the learning process. The workshop's hands-on experience offers a remedy to this shortage of the constructivist approach by providing a comprehensive understanding of the technical aspect of blockchain.

Besides, the constructivist and pragmatic approach is suitable for the training that introduces "new knowledge". New knowledge is intrinsically "unstable", in the sense that the knowledge domain is still continuously evolving. In other words, the training contents mostly have a short life cycle and are subject to ongoing refinement, while this matches the epistemological perspectives of constructivism and pragmatism. Our work demonstrated that our constructivist and pragmatic approach is suitable for blockchain education, especially for IT practitioners.

5.3 Elements of facilitating blockchain education

Three elements can be extracted to facilitate the blockchain T&L process from our analysis results and experiences of this training framework: case study, hands-on laboratory, and trending topics inclusion in curriculum.

Case study is a significant element in facilitating blockchain T&L process. Case study can provide the participants with a fertile basis for theoretical blockchain concepts, and the participants may easily and contextually understand the concept of blockchain through the case study activity (Barnes et al., 1994; Davis, 1993; Escartín et al., 2015). The results of expectations and feedback in this empirical research indicated participants expected the training to contain some successful real-world application examples for interpreting the blockchain concept. The results are understandable because it would provide more evidence for them, so they are more confident in their decisions to adopt the technology to the systems in their workplace and to facilitate blockchain T&L process.

Another element that can facilitate the blockchain T&L process is the hands-on laboratory. Several pieces of research indicate that the hands-on laboratory could facilitate the T&L process in Computer Science subjects (Liu et al., 2019; Deng et al., 2018; Nakagawa et al., 2003). In the same fashion, the T&L process in blockchain theoretically can be facilitated by hands-on practices as well, while the result of this training framework can prove this: 96% workshop participants agree or strongly agree that the training can enhance their blockchain knowledge (workshop post-questionnaire Q7), and 94.1% of them feel satisfied or strongly satisfied with their learning experience (workshop post-questionnaire Q11). In other words, the section providing them with hands-on practice experience (i.e., workshop) can facilitate the blockchain T&L process and provide the participants with a satisfying learning experience.

Moreover, it is recommended to include trending topics in curriculum, though the topics may not be directly relevant to their needs in the workplace, that can arouse the interest of the participants. Before the training, we collected the expectations from the participants, and the result shows that they are interested in sensitive data and cryptocurrency. We therefore added some chapters related to these topics in seminar. It turns out that 92% seminar participants were satisfied with their learning experience (seminar post-questionnaire Q11). Furthermore, the topics related to the feasibility of blockchain adoption were included in the training. This topic lets the participants properly grasp the technology concepts and identify which scenarios are suitable for adopting blockchain technology.

6 Conclusion and future work

Blockchain literacy for IT practitioners is an urgent need due to the rapid growth and prevalence of the technology. Educating blockchain among this population is not as simple as expected, especially for beginners, because it involves both technical and non-technical aspects. In order to provide a better and more complete picture for them and to cope with the challenges, a training framework is proposed to facilitate the T&L process and provide an entry point for IT practitioners with no blockchain knowledge to study blockchain technology. Our framework offers a systematic and flexible approach, which introduces theoretical knowledge and practical skills at appropriate difficulty levels.

Our evaluation results indicated that the implementation of the framework did facilitate the T&L process and fulfilled the learning objectives, as well as the participants were satisfied with the contents by using a constructivist and pragmatic approach. Its effectiveness can be realized from the analytic results. Based on our proposed framework and findings, educators may construct an effective blockchain curriculum and extend the adoption of constructivism and pragmatism to trainings that cover new and emerging knowledge, e.g., metaverse and deep learning. Last but not least, this research extracts the essential elements which can facilitate the T&L process in blockchain education.

Although the training framework is proven to be effective and flexible, there is still room for improvement. To optimize it, the contents of the implementation can be adjusted in future offerings based on the respondents' suggestions by incorporating new and trending topics, including cryptocurrency eco-systems, NFT, DAO. The generic nature of our framework enables such adjustment. However, adopters of our framework may consider extending the training duration and providing more interactive activities allowing the participants to construct, absorb, and reflect on knowledge.

Finally, with proper adjustment of our framework's implementation, the audiences can be extended to other populations with similar backgrounds, e.g., undergraduate and postgraduate students who are specialized in IT-related fields. The implementation can be in terms of seminar and workshop. Depending on learning outcomes requirements, adopters of our framework may consider incorporating more technical contents, e.g., a more in-depth study of smart contract coding and blockchain network configuration, and/or more non-technical contents, e.g., case study and feasibility assessment activities. Our framework serves as the reference basis for implementation, which offers flexibility to cater the audiences from diverse IT backgrounds.

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Declarations

Conflict of Interest None

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