Using a paper-based supply chain game to introduce blockchain concepts

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Abstract

In today's competitive marketplace, companies are strategically utilizing technological advances to gain a competitive advantage, while increasing efficiency throughout their supply chain. One area of innovative technology adoption companies are becoming more aware of is distributed ledger technology, otherwise known as blockchain. The blockchain job market grew over 200% between 2017 and 2018 [1] and is expected to continue to rise. It is predicted that by 2024, the blockchain information technology marketplace will be worth over $16 billion [2] with over 10% of the global GDP stored on blockchain technology [3].

Blockchain has shown early promise in various industries including healthcare, manufacturing, supply chain management, logistics and finance. In the manufacturing industry, blockchain is being considered along with the new area Industry 4.0. Blockchain is crucial in smart manufacturing, as it creates traceable and irreversible audit trails on information which can range from purchasing and transportation transactions to manufacturing process completions. Since blockchain provides crucial information transparency, both industry and academia have been rapidly searching for ways to adopt the technology into their respective fields. Currently, there is little research regarding effective ways of introducing blockchain concepts into higher education courses. This paper will show the effectiveness of using a paper-based supply chain simulation as a pedagogical tool for introducing blockchain, distributed ledger technology, and creating opportunities to change how business transactions and processes are taught in higher education.

Introduction

This paper introduces a paper-based simulation game to introduce students to blockchain technology, with specific applicability for an enterprise resource planning or information and computer technology course. This is accomplished by modifying the "Paper Game" simulation originally developed by the ERPsim Lab at HEC Montreal (https://erpsim.hec.ca/), which demonstrates business processes within an order-to-cash cycle for a manufacturing company at the center of a three-tier supply chain. The term "business process" for this paper is defined as a series of steps undertaken by non-direct-labor staff to produce an output, i.e. business-related documents and/or transactions. The modified simulation developed and described herein introduces a "smart contract" managed by a blockchain network. During the simulation game, students use sticky notes to execute transactions and represent transactional information. The sticky notes serve as information "blocks" within a private, peer-to-peer, blockchain network. The pedagogy allows for class discussion on information dissemination, transparency, timeliness, accessibility, and security.

In general, several factors contribute to the effectiveness of simulations, such as the quality of the students, the quality of the debriefing, and the robustness of the simulation. Four key principles for the use of business simulations include the following [4]:

1) develop students' understanding of business process complexity and dynamics
2) utilize decision making in different, challenging situations in a time-based environment

3) allow students to experience cross-functional information sharing in a silo-based structure
4) measure performance against benchmarks and peers

The first three points are developed through the blockchain paper game's (BPG) procedures and instructor interaction. Research suggests that the 18 to 22-year-old higher-education student demographic from Generation Z, born 1995 to 2012 [5] gravitates to activity-based learning that merges theory with some type of immediate gratification [6]. With respect to this demographic, experience and anecdotal evidence also suggests that there is a lack of understanding of business-to-business (B2B) transactions, the documents involved, and business processes in general. A lack of student understanding and experience tends to hinder understanding the game's inter-company information and documentation requirements, as well as comprehending the potential of blockchain technology. The last point, performance, is benchmarked with a post-game survey, and the peer-to-peer performance is measured by having students measure their company profit to earn extra credit points. This also accomplishes the "immediate gratification" aspect of this activity-based learning exercise.

Presented in this paper is an in-depth overview of blockchain technology, details on the BPG pedagogy, and how it uses business processes and transactional documents to simulate a distributed (blockchain) ledger. Simulations have previously been recorded of increasing student knowledge and retention [6], [11]. To assess effectiveness, student survey methodology is discussed along with data analysis to demonstrate effectiveness of the BPG.

Blockchain Technology Overview

Blockchain technology has rapidly expanded since the first usage of the platform, purportedly by Satoshi Nakamoto, in 2008 as a precursor to bitcoin [7], [3]. Blockchain technology is the combination of peer-to-peer networking and the usage of a distributed consensus algorithm to solve problems that arise in a traditional synchronized distributed database [7]. Blockchain databased are characterized by six key elements: [7]

1. Decentralized
2. Transparent
3. Open source
4. Autonomy
5. Immutable
6. Anonymity

Decentralization refers to multiple computer platforms and occurs as no single platform within the blockchain has all the information. Instead, information is shared among members who have access to the distributed ledger. This is beneficial because if one system were to collapse, others would still have all relevant information. Decentralization increases security and transparency within the blockchain. During a process, i.e. a transaction that adds information to the blockchain, a node (device such as a connected computer) broadcasts the data record throughout the network [7]. After a majority (at least 51%) is reached among the other nodes within the network, the information is recorded as a new block within the chain, with auditable information such as time the block was generated, nonce value (an arbitrary number that can be used just

once in a cryptographic communication), and information of activity record [7]. This process continues with each new record representing an additional block within the chain.

The agreement of what "can" and "cannot" be added to the blockchain from nodes is based on pre-specified rules, such as a smart contract, that cannot be changed unless there is a majority consent among all users within the blockchain [7]. Even if a change is generated, any block of information that has been previously added to the chain is still traceable, as all records within a blockchain are preserved forever. It should also be noted that information is saved at multiple nodes, furthering and enhancing a trust-chain within the system [8].

There are three different types of blockchain systems: public, consortium, and private. The public blockchain is the system that most crypto currencies use. It is important to note that while crypto currencies such as bitcoin are often synonymous with blockchain, they are not the same thing. In cell-phone parlance, Bitcoin is to blockchain as an app (application/widget) is to a phone operating system (e.g. Apple iOS). For a public blockchain, anyone with an internet connection can add or verify transactions that occur within the system. In a consortium blockchain, access to the system can be an open format where anyone can have access, or private among certain members who gain access through permission of developer of the network. This blockchain may be used in business-to-business models [8]. The last system is the private blockchain, in which there is strict authority management gaining permission to the network and data access [8]. In private blockchains, the power to add or view the blockchain is limited to select nodes. Businesses who use blockchain often rely on either the consortium or private model due to the permissioned access [7], [8].

Blockchain has been implemented in a broad array of industries, including logistics and supply chain management, medical, and financial services. Within the logistics industry, specific blockchain applications have been implemented in freight tracking for data authentication, such as freight load boards, resulting in improvements for metrics such as on-time delivery [9]. One documented example of this was the reduction of waste during movement of refrigerated goods. The reduction was credited to the openness of blockchain, allowing every permitted member access to see real-time transportation updates and certificates for travel being readily available as needed [9]. Blockchain has increased the usage of "smart contracts" as well, which are self-executing tasks that are executed automatically when pre-set conditions are met [8], [9]. Manufacturing is the leading industry in deployments of blockchain and cite the possibility of greater cost savings, enhancing traceability, and enhancing transparency as the top three drivers behind making investments into blockchain technology [10].

The Blockchain Paper Game (BPG)

An effective set of computer-based simulations to develop student knowledge of business processes and enterprise resource planning systems (ERP) has been developed by the ERPsim Lab at HEC Montreal. As an introductory tool, the ERPsim Lab also developed a non-software based "paper game" to introduce business processes and concepts to students before engagement with the more complex software-based simulations. The following describes how the original paper game was modified to incorporate basic blockchain concepts. The modified games, henceforth referred to as the BPG, is a two-part active-learning game. The first part has students

play the original game format to learn the basic business processes. At the halfway point, the BPG version introduces two new blockchain related concepts: “smart contracts” and the distributed ledger.

As shown in Figure 1, the BPG uses a three-tier supply chain, with students managing the central (nucleus) company of a three-tier supply chain. There is one upstream supplier and one downstream customer, with students managing the central company as though they are a wholesale distributor of cases of printer paper. Functional areas of sales, purchasing, warehouse operations, and accounting are staffed by student teams of four to run their company. The simulation is played on a virtual week-by-week basis for 10 game weeks. During these weeks, students are repeating a series of steps to procure pallet quantities of paper cases, conduct warehouse operations to store and ship individual cases, and accounting functions to send invoices to customers and pay supplier invoices.

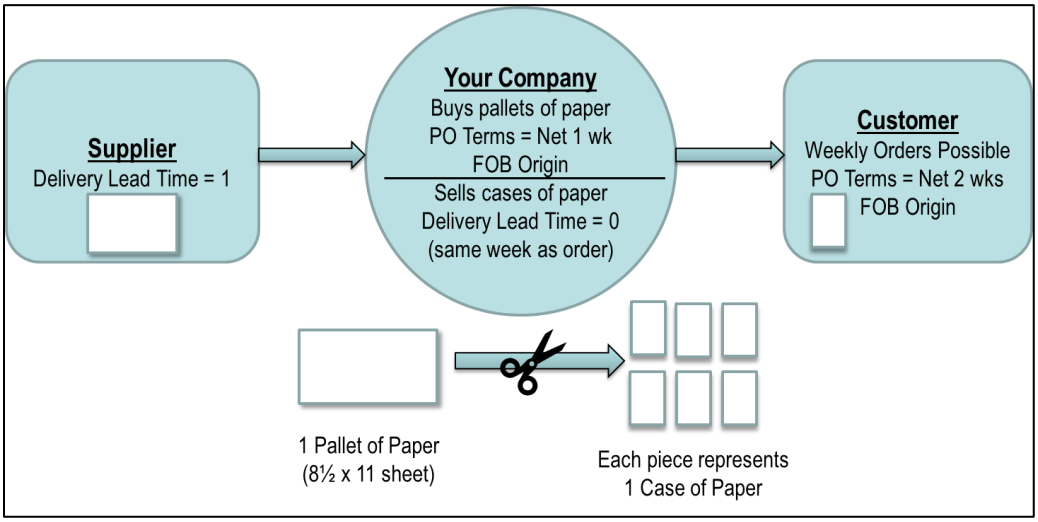

Figure 1. Three-Tier Supply Chain

Students were divided into teams of four and provided templates to create business documents onto sticky notes. External documents such as purchase orders and invoices were written and placed onto large (customer or supplier) game boards to track activity. Sales orders, as internal documents, were passed from sales to manufacturing, and then to accounting as the primary communication tool. The instructor used playing cards to determine random weekly market sales prices and raw material costs, and then generated sticky notes to represent customer payment. An Excel spreadsheet was provided to students, and each functional manager was asked to keep track of information as the game was played. Sales managers tracked market prices and sales volumes, while purchasing managers tracked market cost and purchases. Accounting managers were tasked with compiling sales (revenue) and purchasing (expense) data in order to manage cash flow and report on income and profit.

Figure 2 details the business processes, forms, and flow of information. The color dots represent the colors of the sticky notes used for the game that each student-manager was responsible for generating. On a virtual-week basis, the instructor (game moderator) established a market price for paper cases that students may sell to their customer. The game does not create a customer

purchase order, so the student sales manager assumes an order quantity at his/her discretion and generates an internal sales order to communicate the demand. The sales order informs the warehouse manager on what to ship and the accounting manager on how much to invoice the customer. On the supply side, the game moderator also established a weekly market cost for a pallet of paper. The purchasing manager generated a purchase order and sent it to the supplier (by attaching it to the supplier game board). The game moderator served as the supplier, providing 8½ x 11 (letter size) sheets of paper to represent a "pallet quantity" of six individual cases of paper. The student accounting manager assumed an invoice is sent along with the shipment and issued payment as needed.

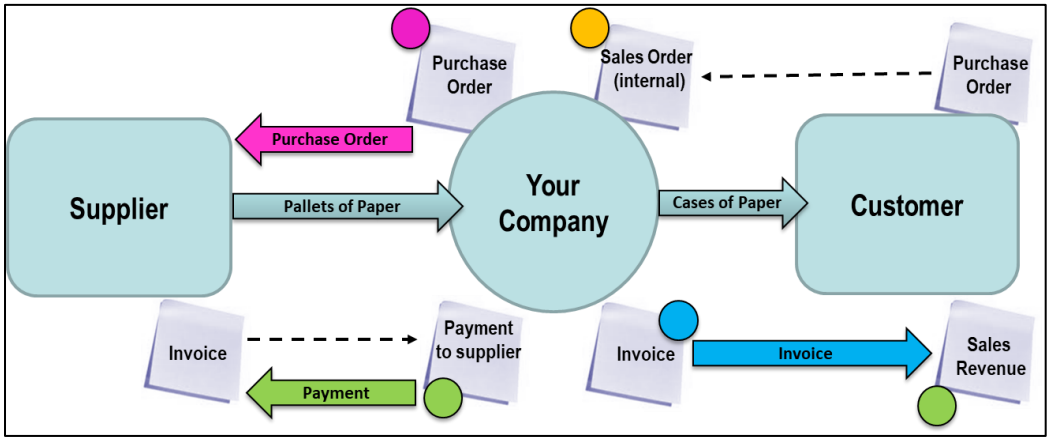

Figure 2. Business Processes, Forms, and Information Flow

Figure 3 shows the completed game boards. Note that the sticky note colors correlate to the business forms from Figure 2. The supplier board is different after week 5. The first five game weeks used the original paper game format and instructed students on various business processes and documents. At the midway point in the simulation, the game took a time-out as teams were asked to analyze information they had been collecting, and to discuss game concepts. Teams were asked to identify their current finished goods inventory, accounts payable, accounts receivable, and profit. Averages were calculated and teams were encouraged to think about how averages may be used to forecast demand and supply for the remainder of the game. The intent of this break was for students to appreciate how businesses need to collect information in order to make decisions.

In the BPG version, the end of Week 5 introduced a "blanket purchase order" as a form of a "smart contract" that would be managed by a blockchain network. Starting with Week 6, students continued use of sticky notes to demonstrate transactional forms, but continuous placement on top of each other represented the "distributed ledger" technology of blockchain. The blockchain represented in this scenario is a private blockchain that encompasses the student company and their supplier. To keep the simulation game simple, no blockchain exists between the student company and their customer, hence business practices continued as per Weeks 1 – 5.

A review of Weeks 1 – 5 on the supplier board shown in Figure 3 shows red sticky notes underneath the green payment. These sticky notes are the standard purchase order representing a single week's quantity. The week 6 column has the last large/red sticky note on the game board;

this is the blanket purchase order representing a total quantity ordered to supply Weeks 6 – 10. Students then issued "purchase order releases against the blanket" beginning with Week 6, represented by the smaller pink sticky notes. In addition, the game moderator added yellow [B] sticky notes to represent a "bill of lading" for the supplier shipment, and yellow [I] sticky notes representing the "invoice" from supplier to customer. Student teams posted payment the same way it was done in the first half of the game. The additional forms were explained during the Week 5 break, along with communicating that the blockchain sticky notes, while placed on the game board, are assumed to be computer entries onto the blockchain virtual private network. The addition of the new supplier documents helped add credibility to the visibility and communication aspect of the distributed ledger technology.

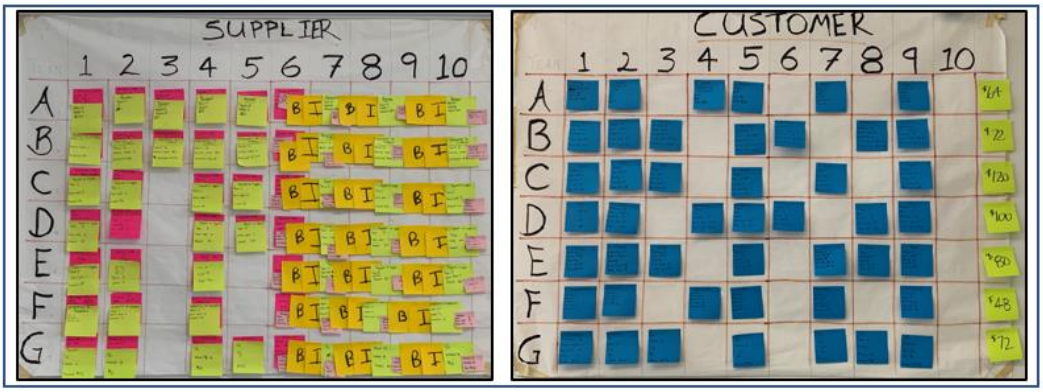

Figure 3. Complete Game Board Example

Figure 4 is the modification of the business processes, forms, and information flow, updated to show the blockchain entries using the node icon to represent a blockchain distributed ledger entry.

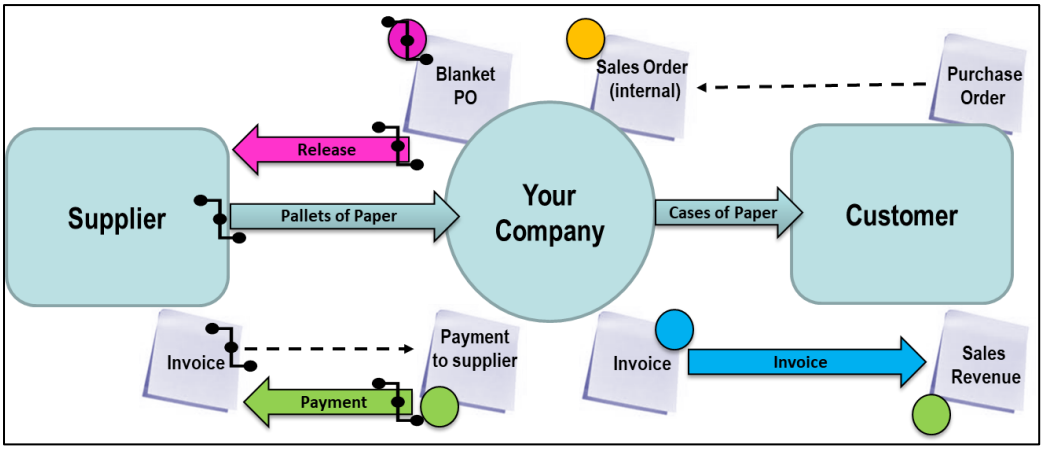

Figure 4. Distributed Ledger (Blockchain) Input Indicators

The intended pedagogy budgets approximately five classroom contact hours. The game was played over 10 rounds, each equal to a simulated week. The first and sixth virtual weeks each took about 10 minutes, and the balance of the weeks took about five minutes. The game was played over several class hours with pauses to reinforce teaching concepts. In a one-hour class format, the first class was used to review the game set-up and rules using a provided Microsoft PowerPoint, review the data collection worksheet, and play a single week. The next class was

used to complete game weeks two through five and assign data analysis homework. The third class reviewed the homework, introduced the blanket purchase order concept along with blockchain and the distributed ledger. Class four was game weeks six through ten with homework assigned to update the data analysis. The fifth class was to review and discuss all the desired concepts and processes developed by the game and instructor.

In the post simulation review, which is the most critical learning aspect of the game, the business processes were reviewed to ensure the information flow and transactional concepts were understood. Also, the instructor asked each functional manager to report average market sales price and raw material cost. While this should be the same for each team, empirical evidence shows that it is usually not, providing a segue into discussion on the importance of data accuracy and the value of information technology.

Research Method

This study utilized an undergraduate introductory course on ERP systems that exposed students to information technology used to manage business processes. The BPG was used as an active-learning technique during the first two class weeks. The active nature of game also served as a tool for students to meet and engage with each other, providing a foundation for peer-to-peer assistance throughout the course. For this study, a private blockchain was simulated between the student company and their supplier, managing a blanket purchase order as a smart contract.

The research utilized a student post-game self-assessment of knowledge acquired, versus a self-assessment prior to playing the simulation. Topics included business process and application of blockchain technology. The survey also contained questions regarding student perceptions towards the simulation itself. Data was collected via a Qualtrics survey instrument immediately after the post-simulation debrief and review. The data sample is comprised of two courses taught in fall 2019 and one course in spring 2020. Students were informed that responses had no impact on their course grade.

Results and Discussion

The total number of survey participants was 65 students. Table 1 summarizes student perception of the effectiveness of the simulation. Responses were coded using a Likert scale, with 5 representing the high end of the positive scale as “strongly agree”, 3 as neutral, and 1 as the lowest negative perception, labeled as “strongly disagree”. Students were asked perceptions regarding the following: likability of the simulation, engagement of simulation, ease of use, and simulation relation to course material.

Overall, it seemed that student feedback was relatively consistent and students both liked and found the simulation engaging. In both instances, over half of students responded with “like a great deal” and “very engaging” respectively. This is critical since previous research concludes that for simulations to be effective, students must both enjoy the simulation as well as find it engaging [6], [11]. Students also responded positively regarding perception of the simulation being “easy” to use. Finally, it is important to note that students believed the simulation aided in

the understanding of course material, i.e. key concepts of the business processes.

Table 1. Student Perception of Simulation Effectiveness (n=65)

Question	Mean	Median	Std. Dev.
1. Did you like the simulations?	4.48	4.00	0.61
2. Did you find the simulation engaging?	4.24	4.00	0.63
3. Was the simulation easy to use?	3.92	4.00	0.82
4. Did the simulation help you understand course material?	4.52	4.00	0.56

Table 2 displays descriptive statistics of student self-assessment of understanding terminology and processes related to blockchain technology before and after participating in the simulation. Responses were coded using a Likert scale with 4 representing "very proficient," 3 as "somewhat proficient," 2 as "not proficient," and 1 represented "no knowledge or understanding" of a concept. Students were very open in their pre-simulation assessment, admitting to being "somewhat proficient" in many of the categories associated with the topics covered in the simulation. Student assessment ranked the lowest in the assessment of private blockchain processes with a mean of 1.97. The highest rated pre-assessment was regarding cryptocurrency and bitcoin terminology with a mean of 2.25. This was not surprising since the word "bitcoin" is more frequently used than other blockchain terms and processes. [7]. The concept of blanket purchase orders was also measured as this was an addition to the original game. Students perceived this to be their second area of most knowledge with a mean of 2.23.

For the post-simulation self-assessment, all students recorded an increase in ratings across all categories. Literature suggests that when conducting self-assessments, students may often view their ability higher than the reality of attainment [12]. From data observation it appeared student perception from the areas surveyed moved towards a "somewhat proficient" belief overall. The areas that increased with the most self-perceived belief in gains were: 1) the concept of blanket purchase orders (3.47), and 2) blockchain concept and capabilities (3.24).

Table 2. Descriptive Statistics for Blockchain Concepts (n=65)

Student Proficiency Self-Assessment (knowledge and skills)	Mean		Median		Std. Dev.	
	Prior	Post	Prior	Post	Prior	Post
Concept of Blanket Purchase Order	2.23	3.47	3.00	4.00	1.01	0.67
Cryptocurrency and Bitcoin Terminology	2.25	2.98	2.00	3.00	0.88	0.71
Blockchain Concept and Capabilities	2.18	3.24	2.00	3.00	0.89	0.64
Blockchain Terminology	2.03	2.98	1.00	3.00	0.89	0.81
Private Blockchain Processes	1.97	3.00	1.00	3.00	0.90	0.80
Smart Contract Terminology Processes	2.05	3.02	1.00	3.00	0.93	0.81

Conclusion and Limitations

The primary purpose of this study was to assess whether student knowledge of blockchain processes and terminology was developed or expanded by using the BPG simulation. The first impression from the data indicated that the implementation of the BPG into the curriculum showed positive results. Students liked the simulation and found it engaging. One student noted,

> "*The game really allowed you to go through the process in a business setting to really grasp the concepts we have been learning about. It was fun and challenging which I feel helped to understand what really was going on*."

Several other students echoed similar sentiments when asked to elaborate about their experience. No student who elaborated on their BPG experience stated negative opinions or attitudes about the simulation.

Students reported they found the simulation engaging, easy to use, and that it assisted in relating course material to real-world applications. Additionally, students' perceptions of knowledge prior- and post-survey changed as well. As expected, perception increased in all areas after playing game. However, while overall perception of skills seemed to increase through participation, some students did not feel proficient in the concepts and processes of the BPG. Unfortunately, students in this category did not provide any free-response feedback as to why. Future studies will expand the survey to ask students that rate below-proficient levels to explain and suggest ways to improve the simulation experience. Regardless, the authors feel it is still in a student's best interest to continue using the BPG as research has shown that learning occurs naturally because of participating in a simulation exercise [13].

This study also provided additional evidence of positive results for the use of an activity-based learning experience to develop a frame of reference for students as they proceed further into blockchain concepts and processes. Besides providing building blocks for blockchain terminology and transactional data needed within a functioning business blockchain, the BPG also served as a team building activity. This is noteworthy as team composition and skills have been identified as being a critical success factor for ERP system implementations [11].

While not necessarily a limitation, the BPG only explored a private blockchain between two businesses. This was done due to time constraints as well as trying not to over-complicate blockchain concepts and processes, potentially inhibiting student learning. A game dedicated to blockchain could start in Week 1 with the current game's Weeks 6 – 10 concepts, and then at the midway point, incorporate a blockchain for the downstream facing, customer transactions.

As previously stated, the blockchain market will continue to grow [1], [2], impacting a wide array of industries. To react to this new technology, academia must be prepared to adapt curriculum as industries begin to adopt new technologies. The BPG served as an introduction for students to familiarize themselves with blockchain and the distributed ledger technology.

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