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INFORMATION SYSTEMS EDUCATION JOURNAL

Real-Time Visual Analytics: An Experiential Learning Activity for Undergraduates

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Abstract

We describe a "Day of Giving" university fundraising event that can be used to introduce data visualization to undergraduate students. The project involves integrating data sources, creating a Tableau data model, and designing a heat map that can be embedded into a front-end website. Our activity provides opportunities to discuss various technological concepts, such as: client/server networks, front end web development, backend database servers, database design, sources of data, data preparation and cleaning, data management, webhooks, real-time data collection, and visual analytics. For the purpose of this paper, we focus on concepts related to sources of data, real-time data collection, visual analytics, and webhooks, as well as security and ethics issues that arise from these activities. Additionally, we explain how instructors can choose to implement the activity as an exercise during a single class session or as a team project over a longer period. Both approaches provide students with experiential learning opportunities in data analytics. First, we outline fundamental concepts for instructors to introduce at the start of the activity. Second, we introduce the context for the activity, a heat map to display donation amounts by location in real-time. Third, we discuss the tools we used to feed data to the visualization. Fourth, we describe steps for instructors to follow to replicate the project. Lastly, we provide discussion points to explore security and ethics issues related to data analytics.

Keywords: analytics, data visualization, experiential learning, pedagogy

1. INTRODUCTION

A conceptual discussion of how technology works provides the basis for experience. A hands-on experience with technology helps students retain concepts (Christen, 2009; Hsiao, Chen, Lin, Zhuo and Lin, 2019). Such experiences are sometimes difficult to create in a classroom environment due to time constraints (Gillies and Boyle, 2010; Le, Janssen and Wubbels, 2018) and the availability of the appropriate technology isolated from campus networks (Mew, 2016). Entry level, undergraduate courses need to introduce technical concepts to students who often have very limited hands-on experience with technology. And, these students need positive encounters that enhance their technological self-efficacy (MacLeod, Yang, Zhu and Shi, 2018).

A key concept to address when introducing business analytics is the use of data visualization to aid decision making (Adkins, 2016). For some organizations, it is also important that visualizations to be provided in real-time (Toasa, Maximiano, Reis and Guevara, 2018). While providing students with data visualization experience is generally straightforward, creating hands-on experiences that simulate the collection of real-time data is more challenging. A common example of real-time data collection that will be familiar to students is a dynamic Internet website.

Most universities collect real-time data that they want to share with internal and external stakeholders. An example would be when the Advancement office at the university wants to show the result of a fundraising campaign. Fundraising events and their results are often shared online publicly. In this paper, we demonstrate how an institutional need can be leveraged into an experiential learning activity, an in-class exercise, or a team project. In our exercise, students create a Tableau heat map for a "Day of Giving" which is updated in real-time as donations flow to the website. The links between the Tableau heat map and the website are created via webhooks using free, open source applications. The event can be introduced as a mini-case and the activity can be replicated as a simulation where the instructor walks the class through the process. The concepts, case, and activity could be integrated into an undergraduate introductory business analytics course, a visual analytics course, or even an ecommerce course.

Prior to facilitating the class activity, instructors should present students with conceptual information in support of the mini-case and in-class project. This can be done in a variety of ways, but we suggest two possibilities: (1) as part of a class lecture or (2) as a flipped learning activity outside of class. Our case provides opportunities to discuss various technological concepts, such as: client/server networks, front end web development, backend database servers, database design, sources of data, data preparation and cleaning, data management, webhooks, real-time data collection, and visual analytics. For the purpose of this paper, we focus on concepts related to sources of data, real-time data collection, visual analytics, and webhooks, as well as security and ethical issues that arise from these activities.

2. THE CONCEPTUAL INTRODUCTION

In the conceptual introduction, instructors should discuss data sources, data preparation, visual analytics, real-time data collection, and webhooks. If presenting the material in class via lecture, we recommend that response system software be used to engage the students in discussion and feedback. If a flipped learning activity is required outside of class time, then we recommend that a graded quiz, implemented through the university learning management system, be developed to ensure that each student covers the material prior to the in-class activity. In this section, we provide a brief synopsis of the conceptual material that should be covered before beginning the in-class project.

Data Sources, Preparation, and Cleansing

A discussion on data sources should include where data can be found, various data formats, types of data, data messiness, and the need to clean and prepare data prior to analysis. Issues like the size of the data source, the accuracy of the data, data security, and data redundancy should be discussed. Instructors should also introduce relational databases and referential integrity concepts. Something simple like a Microsoft Excel workbook can be used to illustrate all the potential problems that lead to data difficulties and the need to clean and prepare data. An overview of a tool like Tableau Prep Builder could also be used to discuss data cleansing and preparation.

Visual Analytics

Next, instructors should provide background on the purpose and function of visual analytics. Data visualization helps people more easily understand information contained in data as opposed to viewing raw data or a mathematical algorithm. Visualization also helps people grasp difficult concepts and identify patterns in data. A variety of resources are available to illustrate the power of information visualization (e.g., Ware, 2012). The forecasting tool built into Microsoft Excel could be used to illustrate these points.

Leveraging Real-Time Data Collection

Instructors should explain what "real-time" means in terms of computer systems. A point to emphasize is that a system processing event generates a signal that indicates an event has occurred. That signal can act as a trigger to access and gather data associated with the event. To extend the conversation, the importance of real-time data analytics to decision making can be illustrated in examples like stock trading, hospital patient care, inventory management, or fraud detection. The most common type of real-time data visualization is a dynamic Internet website, such as database driven websites. A simple example that students can understand is a baseball website, where the data being displayed changes with every pitch during a game.

Students can also relate to social media examples. Illustrating how businesses scrape twitter data in real time to perform analysis on trending hashtags in order to refine their marketing campaigns is a relevant business example that students understand.

Extract-Transform-Load (ETL) Webhooks

Students also need to understand that a webhook is a method used to deliver data from one application to another in real-time. The system events that serve as the triggering events for the webhook are described while introducing the importance of real-time data analytics. Webhooks look for a specific event (e.g., when a customer completes a purchase on an ecommerce site). A couple of examples can be mentioned, such as MailChimp, which uses a webhook to signup visitors of a website to a newsletter, or PayPal, which uses a webhook to tell QuickBooks that a client has paid their invoice.

3. THE MINI-CASE AND IN-CLASS ACTIVITY

The idea for an in-class data visualization activity emerged from an undergraduate independent study where one of our students completed a similar project based on an actual need at the university. Internal civic engagement projects not only aid both the university and the students but can often be turned into in-class activities that provide experiential learning opportunities.

The mini-case that we developed centers around a university advancement event called a "Day of Giving". Most universities are non-profit organizations that rely on donations to help fund the operations of the academy. A "Day of Giving" is one tactic institutions use to garner donations. The idea is to set aside a special day to celebrate the university and to recognize all the people who care for and support the institution. Stakeholders are then targeted for donations on that day. A running total of donations is captured and presented to the public through a website.

We discuss how alumni and other friends of the university are located throughout the United States. The university advancement team recognizes that a geographic heat map of donor generosity, presented in real-time, would be an interesting addition to their "Day of Giving" website. The purpose of this visual would be two-fold. First, it represents the geographic breadth of giving, and second, it creates a sense of visual competitiveness. You can imagine a potential donor viewing the map and thinking "my state, my city, is giving the most. We are winning." However, the advancement team is not sure how to bring the idea to fruition, so they use their internal contacts to ask for help. A management information systems instructor offers to have undergraduate students create the heat map at no additional cost to the university.

4. TECHNICAL ASPECTS OF THE PROJECT

The independent study project consisted of four parts using four different tools. First, the university was contracted with MobileCause, a fundraising service that provided a front-end website that acted as the "day of giving" interface to capture donations and location data. To maintain consistency, we emulated the MobileCause website used by the university for their actual day of giving.

Second, we used Stitch, an open source extract-transform-load (ETL) application that allows for webhook integration. Stitch collects the data "ping" from the front-end website and delivers the data to our data warehouse. Stitch is a good choice for this project because the service is free for the first five million rows of data. Given the limited scope of our project and in-class activity, we were not concerned with exceeding the five million row limit.

Third, we used data.world as our cloud data warehouse. We chose data.world to host the data because it was free to use and integrate with Stitch. The free individual account allows for 3 projects/databases with a 100MB limit per project/database.

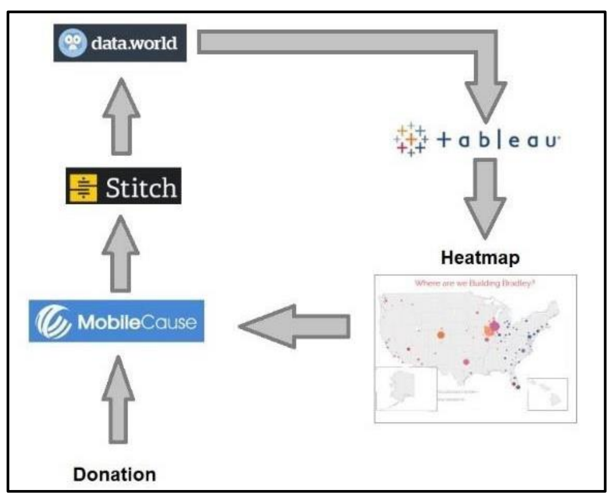

Figure 1: Project Process Map

Lastly, we selected Tableau as our data visualization tool. We connected Tableau to our data.world database and built the data model using the geographic data. Once everything was fully configured, the heat map was embedded into the front-end website (see Figure 1).

Various aspects of the project could be built either ahead of time or as part of the in-class project depending on the needs of the course. The front end (donation website) and back end (Tableau data model and heat map) can be prepared for the students or the students could build them from scratch or finish either end as needed. For our in-class activity, we created the front-end website ahead of time, identified the additional data sources for the Tableau model, then cleaned and prepped those sources. The students can then create the data integration, build the Tableau data model, and design the heat map.

5. IN-CLASS PROJECT PROCESS

To leverage the project into an in-class activity, we begin by previewing a donation website that consists of two simple pages and emulates an online donation website. The homepage provides an explanation of the imaginary day of giving and is where the heat map will be displayed. The second page contains a donation form.

Depending on how hands-on you want the project to be, you can use a single website or replicate the website for each student in the class. An online web hosting service provided us with a free developer account so each student in the class had their own development website.

Stitch Integration

The first step to get Stitch functional is to connect it to the donation website by adding a new integration. Stitch will integrate with a variety of sources, such as BigCommerce or Shopify. For example, with Shopify, you would create a unique integration name and provide the name of the Shopify shop you are using. The integration process between the two sources is automated. Alternatively, if you have your own web server and website, Stitch can generate a webhook URL that can be used via an HTTP POST in a PHP script. Webhooks can be generated through the integration feature on the Stitch website (see Figure 2). Either method creates an active link for real-time data collection.

The webhook integration requires a name and primary key. The primary key field should be left blank. By leaving the primary key field blank, Stitch generates a unique primary key for each data record scraped from the donation website. Once saved, Stitch generates a webhook URL that links to the front-end donation website. Data collected from the front-end website will be delivered to the webhook URL. Stitch then feeds the scraped data to a data warehouse.

Data.World Data Warehouse

After creating a Data.World account, students can create a new dataset and give it a name. Each student should then integrate their Stitch account through both Stitch and Data.World. Using the destination link in Stitch, a form will pop up and the student will enter their Data.World account ID. The data is automatically stored in JavaScript Object Notation (JSON) format. Stitch will test the connection; if the connection is successful, then the process is complete.

Finally, permissions must be granted from data.world to allow Stitch access to the data. First, go to “Your Integrations” from the data.world site. Next, edit the integration and check if it is enabled. If it is not enabled, the permissions may need to be granted. If needed, both Stitch and data.world have extremely helpful documentation that can walk you through each step of the process.

After the connection is enabled in both Stitch and data.world, the data can flow in real-time from the donation website, through Stitch, and into the data.world database. We have found that the process from donation to data.world takes roughly 15 minutes. You can have the students enter dummy data through the donation website or you can create a script and trigger it to feed some preset data into the system. In Data.World, the data can be viewed in the user account accessed via the Internet. In addition, the data can be queried, if so desired. For example, you could ask students to write a query to count the number of donations over $100. We didn’t do this for the project because the main purpose of our data.world connection was its ability to integrate easily with Tableau.

Integration with Tableau

Just like with Stitch, to integrate Tableau with data.world, go to “Your Integrations” and connect to Tableau. As needed, check and enable permissions. Using the web data connector in Tableau, a connection is made to the data.world URL.

One of the issues we encountered is queries created in Tableau Desktop do not establish a live connection to the data.world data. In Tableau Server or Tableau Online, extracts can be refreshed every 15 minutes to match the feed through the pipeline. At first, we considered this a problem, but we then realized it was an opportunity to discuss the differences among Tableau versions, such as how they work in organizations that use Tableau Server versus the desktop version.

This step also provides the opportunity to discuss Tableau Bridge, a resource that can maintain connections to data sources that Tableau Online cannot reach directly.

Tableau Data Model

The data collected in the database includes the zip code for each person submitting a donation. Our design is based on showing donations by the 210 recognized media markets in the United States. Therefore, we need a data source that creates a relationship between the donations and the media markets. A free source of all U.S. zip codes is easy to find online. However, finding a free source that links each media market to each zip code currently doesn't exist. A listing of media markets is available, but a considerable amount of data preparation is necessary to create the one-to-many relationships needed for the data model. We don't take students through this process for the in-class project, but we do explain it. Depending upon your needs, it would be possible to include this step, but you would have to expand the project across multiple class periods. Given that we are introducing much of this material conceptually in a lower level undergraduate class, we don't feel it is necessary. Although, a brief explanation might be useful for those interested in replicating the process as a class exercise.

The zip code database (see Figure 3) lists every zip code in the United States and its designated market area (DMA). These markets are geographical areas where all residents receive the same broadcast offerings, including television stations and radio stations. The bulk of the Zip code data is available for free from ZipCodes.org (https://www.unitedstateszipcodes.org/zip-code-database/) and downloadable as an Excel workbook. But, the source doesn't come with the DMA data. We added that data ourselves. For the purposes of the exercise, the two Excel workbooks (zip codes and media gps) are cleansed, prepped and ready to go. At this point in the exercise, instructors can briefly revisit the concept of cleaning and prepping data sources.

As for the designated market areas workbook, that information is also downloadable from a variety of web sources. But, the GPS coordinates are not included. Instructors can review the data prepping process by demonstrating a free online geocoding tool, such as mapdevelopers.com used to find the latitude and longitude of the most prominent city in each DMA. This city served as the central point where the heatmap would place the mark to signify a donation in that DMA (see Figure 4). Both workbooks are available to interested parties upon request.

If instructors provide the students with the workbooks, then a data model consisting of two one-to-many relationships can be constructed in Tableau (see Figure 5). The transaction report is the link to the data.world database. The basic entity relationship diagram is shown in Figure 6.

Tableau Heat Map

Creating the simple heat map in Tableau is straightforward. Using the default circle as the mark, the sum of the collected donation amounts is used for the size, and the DMA is used for the color. The latitude and longitude from the Media Market spreadsheet are placed in the columns and rows to generate the map. We restrict it to the lower 48 states in the U.S. (see Figure 7). At this point, the instructor can feed additional data through the pipeline via the donation website and students can watch the map update in real-time.

Adding the Heat Map to the Website

The final step involves adding the heat map to the donation website. Using Tableau Public or Server, you generate some code to embed into the website. If you are using an online developer platform, you can simply edit the page and paste the code into the appropriate space.

Given the time restraints of a single class, we recommend having the instructor demonstrate this process. Therefore, the Tableau Public or Server account, setup, and design should be in place prior to class. During the demonstration, the instructor can explain the purpose of Tableau Public and/or Server, and how they are used.

Final Product

At this point, for our exercise, the final product is just a dynamic heat map embedded on a single web page without any other information. The dummy "donation" website is a work in process and will develop into something more meaningful as we continuously improve the exercise.

This exercise evolved from an independent study where one of our students worked on an actual day of giving project for our university. If you want an idea of what the finished project might look like as we continue to refine our website for the exercise, this URL will take you to that project https://www.bradley.edu/sites/building-bradley/

6. SECURITY AND DATA ETHICS

Due to the rise of big data and the development of increasingly powerful analytical tools, we believe that these issues must be integrated throughout the entire information systems curriculum as much as possible. Therefore, once the data visualization aspects of the in-class activity have been completed, we also encourage instructors to discuss issues related to security and data ethics.

For example, students will have access to the entire donation database, which includes the donor names and complete addresses. Yet, the only information needed to create the heat map is the donation amount and donor zip code. This provides an opportunity for instructors to demonstrate how providing analysts with full access to sensitive and identifiable data, especially data that is not needed for the task at hand, can increase the risk of a breach. Instructors can then explain the need for access controls, encryption, anonymity, and data minimization.

There are also several questions that can be discussed from a data ethics perspective. For example, many donors might wish to make an anonymous gift. If a donor elects to keep their contribution anonymous, should their donation data be included in the heat map? What if only one alumnus lives in a given zip code? Are there any other data sources that, when combined with the heat map data, might reveal the identity of an anonymous donor? Further, what disclosures should be provided on the donation website?

To reduce the risks associated with big data and data analytics, students must develop the ability to identify ethical issues and potential threats to privacy and security prior to accessing data. Including an ethical component and discussing how technological advancements can sometimes lead to negative outcomes will help students recognize and mitigate similar risks in the future.

7. CONCLUSION AND STUDENT FEEDBACK

For many years, pedagogical research has recognized the value of learning with technology rather than simply learning about technology (Schuldt, 1991; Podeschi, 2016). Today, researchers recognize hands-on, class projects as active, experiential learning tools for students well suited to a flipped classroom approach (Wu, Manohar and Acharya, 2016). Our data visualization activity presents such an opportunity for instructors. We can see it being used in an introductory business analytics course, a database course, or even as part of a survey course on electronic commerce. It should be noted that our experience with the exercise is nascent. We haven't tried it out in multiple courses but the plan is to do that and collect additional information in the process. We did interview students, post exercise, to gain insights into the experience and to further improve the activity.

In general, the students felt that the exercise brought the conceptual material to life. And, they appreciated getting some actual hands-on experience with technologies that most of them had never heard of let alone used. Their main criticism was that they felt a little lost because they really hadn't absorbed the conceptual material to the point where they could connect specific material to individual parts of the exercise itself. This seems to be a pedagogical design issue. It might be best to intermingle the conceptual material and in-class activity over two class periods. This would force us to slow down and use tools like in class polls to see how well the students are connecting the conceptual material to each part of the project.

We would posit that the in-class exercise allows individual instructors to have some flexibility in how they manage their time constraints, how much setup to complete prior to class, and how they want students engaged in the project. For our purposes, we see this project as appropriate for students learning about these concepts and tools for the first time. We want to keep it simple and limit the amount of actual hands-on work. Given the variation in student abilities, their technological self-efficacy, and the possibility of technological glitches, this exercise can be accomplished in a single 75-minute class period. But, we will continue to experiment with the pedagogical design.

The purpose of our exercise is to give meaning to the conceptual discussion by letting students perform some of the tasks necessary in making the project work without needing multiple class periods. At the same time, we recognize the opportunity to turn this into a full-scale project that could be required as an assignment outside of class time. We believe such a project would be more appropriate for advanced undergraduate students. Our hope is that this paper would provide the groundwork for anyone who would want to develop such a project for students.

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Appendix A: Additional Figures

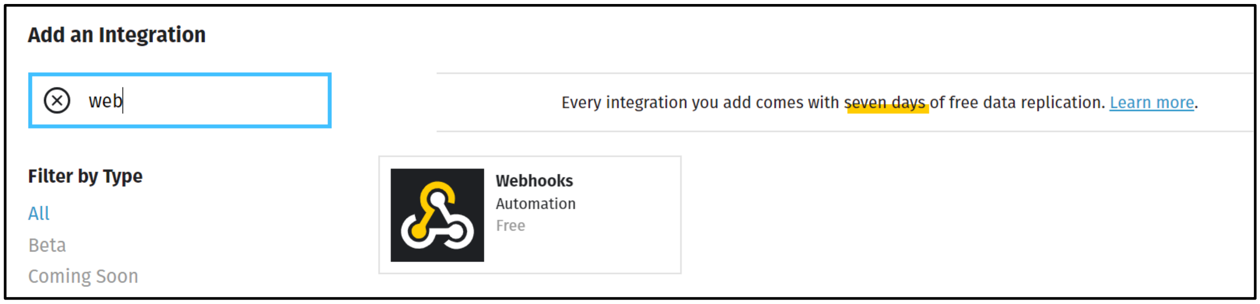

Figure 2: Webhook Integration with Stitch

zip	type	primary_city	state	county	timezone	area_code	country	DMA
36066	STANDARD	Prattville	AL	Autauga County	America/Chicago	334	US	698
36068	PO BOX	Prattville	AL	Autauga County	America/Chicago	334	US	698
36003	STANDARD	Autaugaville	AL	Autauga County	America/Chicago	334	US	698
36008	PO BOX	Booth	AL	Autauga County	America/Chicago	334	US	698
36067	STANDARD	Prattville	AL	Autauga County	America/Chicago	334	US	698
36749	STANDARD	Jones	AL	Autauga County	America/Chicago		US	698
36051	STANDARD	Marbury	AL	Autauga County	America/Chicago		US	698
36006	STANDARD	Billingsley	AL	Autauga County	America/Chicago		US	698

Figure 3: Zip Code Spreadsheet with DMA

Rank	Market	State	Latitude	Longitude	DMA
165	Abilene-Sweetwater	Texas	32.45464	-99.7383	662
152	Albany, GA	Georgia	31.5776	-84.1763	525
59	Albany-Schenectady-Troy	New York	42.6664	-73.7987	532
47	Albuquerque-Santa Fe	New Mexico	35.10555	-106.647	790
179	Alexandria, LA	Louisiana	31.29345	-92.4702	644
208	Alpena	Michigan	45.07448	-83.4383	583
131	Amarillo	Texas	35.20038	-101.828	634
147	Anchorage	Alaska	61.14834	-149.195	743
10	Atlanta	Georgia	33.76265	-84.4231	524
105	Augusta-Aiken	Georgia	33.36446	-82.0708	520
40	Austin	Texas	30.30718	-97.756	635
122	Bakersfield	California	35.35015	-119.031	800
26	Baltimore	Maryland	39.30098	-76.6106	512
155	Bangor	Maine	44.83227	-68.7906	537

Figure 4: Media Market Spreadsheet

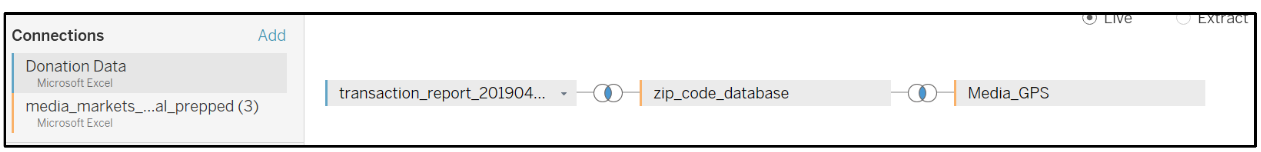

Figure 5: Tableau Data Model

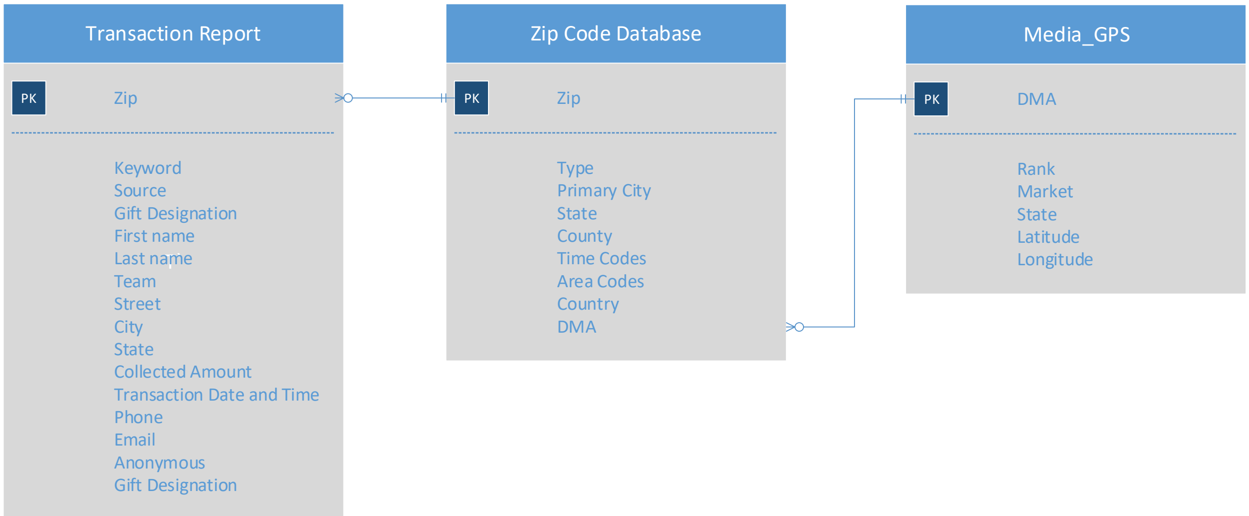

Figure 6: Entity Relationship Diagram

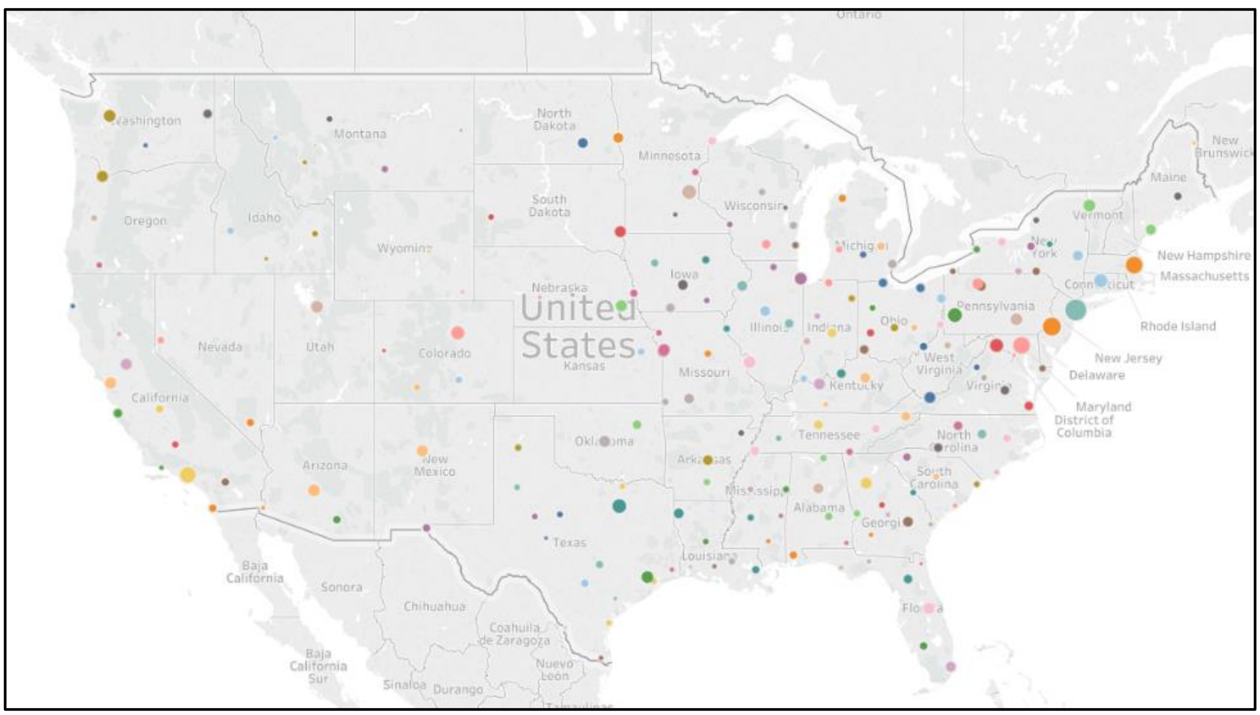

Figure 7: Example Tableau Heat Map Output

eXtensible Computing Curriculum Reporting Language (XCCRL)

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Abstract

Just as the adoption of eXtensible Business Reporting Language has standardized the exchange, transmission, and reporting of accounting and financial data, this paper proposes the eXtensible Computing Curriculum Reporting Language as a standard for the exchange, transmission, and reporting of computing curriculum information in hopes of achieving semantic comparability among the descriptions of the computing disciplines. This specificity in the extension of eXtensible Business Reporting Language to the computing disciplines in the form of eXtensible Computing Curriculum Reporting Language acknowledges the nascent and emergent nature of computing and the need to reconcile, semantically, between uses of computing terminology and concepts to achieve clarity. This paper provides a brief background on eXtensible Business Reporting Language and demonstrates how the same concept may be applied in computing curriculum reporting. This paper is related to efforts to support the Computing Curricula 2020 initiative of the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers and represents the ongoing work of the Education Special Interest Group Standing Committee on Curricular Matters.

Keywords: eXtensible Computing Curriculum Reporting Language, XCCRL, Computing Curriculum, Computing Curriculum Reporting, Computing Curriculum Mapping, Taxonomies

1. INTRODUCTION

Among its many uses, the curricula that are published by computing programs, institutions of higher learning, or by the organizations and agencies that support these institutions, constitute a communication regarding the nature of the knowledge about which the curriculum is focused and the outcomes which the learner will achieve. In effect the curriculum is a communication about the curricular elements within the curriculum such as knowledge areas, learning units centered about skills, and learning outcomes to be assessed and observed. However, the natural language we use to describe these elements is not sufficient to ensure that intended meaning within these descriptions are comprehended as intended. As a simple example lies with the term "database." For the manager, accountant, systems analyst, database administrator, software developer, computer scientist, mathematician, and computer engineer, this term connotes a distinct set of concerns. Thus the knowledge areas, while overlapping, will be dissimilar as each of the roles above assumes a different disciplinary disposition, a unique set of practical concerns, and a history of engagement with the actual computing phenomenon implied in the term "database" that is contextually and historically shaped.

This issue of communicating computing curricula concepts has three principle components: issues related to the complexity of human communication, issues related to overlap in the conceptualization and contextualization of computing phenomenon predicated on required utility, and the need to differentiate these meanings and uses to achieve clarity and understanding for those within and without the computing disciplines. We shall characterize each of these against the assumption that a curriculum is a human communication and is subject to facilities and constraints afforded within human communication.

Responsibility for the reconciliation of meaning could come from a variety of sources. Should there be a need for public or fiduciary accountability, it is possible that such issues would be regulated, and the compulsion of compliance would facilitate a reconciliatory apparatus. There are also informal structures that could reconcile the semantic differences; however, these are ephemeral and subject to distortions and bias that would potentially conflate attempts for reconciliation. A professional and/or disciplinary approach is possible, perhaps assisted by regulatory authorization, such that a professional society, typically charged with performance, ethical, and procedural regulation within a discipline, could provide the leadership necessary.

In the case of computing, this leadership does exists with societies such as the Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM), however, computing remains a mostly under-regulated endeavor where the lines between amateur and professional are indistinct and, arguably moot given the inherently emergent nature of the work and the accessibility of many of the tools about which acute skills are necessary. To wit, an "amateur" with a computer, hard work, and ingenuity, may conceive of, craft, deliver, and profit from highly impactful implementations of computing skills and knowledge and remain entirely outside of any professional oversight. As such, the constraints and restraints that are often byproducts of the regulation from the professionalization of a discipline has a difficult time in the case of computing.

The freedom by which many, but not all, of the skills of computing may be acquired and purveyed, suggest not only that the reach of a curriculum will not ensure uniformity in expected professional practice (as would be the case in Law or Medicine outside of the particulars in the localization of licensure), but also that the impact on public perception of computing will be equally non-uniform. Whereas the certification of knowledge matters in so many other impactful areas of human endeavor, in computing, this is less so.

We do not offer the previous derivation to suggest that this issue of semantic clarity in the articulation of computing curricula is intractable, just simply that it is fraught. Nonetheless, an opportunity for leadership lies with the academy such that academics in the computing disciplines may establish maps between concepts such that when a term like "database" is used, there exists a mutual or common understanding. This is undoubtedly a vast ontological, taxonomic and epistemological undertaking and to propose a comprehensive solution within the confines of an academic paper would be ambitious, to put it politely. Rather, the aim of this paper is to reference a solution for semantic reconciliation in the reporting of financial data in the accounting, finance and banking realm to extrapolate lessons from that context onto the computing context.

This paper offers a conceptualization of an eXtensible Computing Curriculum Reporting Language (XCCRL) to support extant efforts of the Computing Curricula 2020 (CC2020) project to produce tooling that offers the visualization, articulation, and exploration of computing curricula to develop a maturing understanding of the interconnectedness between computing disciplines and also into other human endeavors and the disciplines that surround them. We appropriate lessons from the development of the eXtensible Business Reporting Language (XBRL) as a guide and contrast this with the same need to reconcile between semantic meaning embedded in computing terms and phenomena. Our proposed derivation, the XCCRL, is modeled closely on the XBRL and should facilitate interchange between the prototypes and tooling developed by the CC2020 project. Further, it may perhaps serve as an interchange between the computing disciplines and their constituents by way of curricular descriptions for public use. Much as genres serve to signal semantic content in entertainment media such as movies, books, television programs, and video games, it is hoped that the semantic groupings within the terms used to describe computing curricula may also be reconciled through an effort such as XCCRL, in a similar way that XBRL makes use of semantic meaning.

This paper explores these issues by first reflecting on the fundamental issues of human communication in reconciling meaning among computing terms. Next we explore how XBRL has addressed similar issues in the realm of financial data reporting. We next propose how the features of XBRL could be appropriated into the computing curricula context. This is followed by a brief account of how XCCRL may assist in the under-way efforts of the CC2020 project and the plans to develop prototype information systems and tools use to explore semantic meaning in computing curricula. We conclude with future steps to realize XCCRL, some limitations in extrapolating from XBRL, and conclude with why XCCRL, or a similar solution, will be necessary to assist in the further professionalization of the computing disciplines if those disciplines will make headway in realizing the positive benefits that professionalization may hold for the human activities that are most impacted by computing.

2. A SEMIOTIC TREATISE ON MEANING IN COMPUTING TERMS

For simplicity, it is possible to describe the issue of reconciling semantic meaning for computing terms according to those who use the tools, artifacts and general phenomena of computing and those that conceptualize, design, develop, and articulate these outputs. Between them, these groups articulate a language - replete with terms, concepts, and intensions – that facilitates transactions. What is transacted are needs and fulfillment of needs that shapes the supply and demand exchange in an emergent manner. This is so for other economic systems and is evident in computing. However, there is an expert/non-expert dimension to these exchanges where expert terms fall into common parlance and non-expert approximations, metaphors and allegorical utterances also permeate the lexicon between the suppliers and consumers.

<table>
<tr><td colspan="2" rowspan="2">Computing Producer/Consumer Matrix</td><td colspan="2">Supplier</td></tr>
<tr><td>Expert</td><td>Non-Expert</td></tr>
<tr><td rowspan="2">Consumer</td><td>Expert</td><td>A</td><td>B</td></tr>
<tr><td>Non-Expert</td><td>C</td><td>D</td></tr>
</table>

Table 1. Conceptualizing the Producer/Consumer Relationship in Computing Outputs

The conceptualization in Table 1 illustrates the issue. We propose that the lexicon and language that surround computing is shaped by exchanges in a matrix formed by expert and non-expert language used in the production of computing outputs, artifacts, and phenomena and the expert and non-expert consumption of the same. While other models would be possible, we use this model to propose and illustrate the cases where the language used, and thus the conceptualization begins and shapes the meaning exchanged in the producer/consumer relationship. Table 2 below provides examples and illustrations of each of the interaction cases – A, B, C, and D – described in Table 1.

Interaction Case	Description
Case A	Many business-to-business transactions occur in the context of the specification of computing requirements by trained professionals to be fulfilled in the design and development activities of trained professionals
Case B	Crowdsourcing, customer co-creation, and similar reliance on non-expert input to shape design requirements. In this case, the supply is use behavior.
Case C	Most Commercial-Off-The-Shelf-Software (COTS) and information services operate under this model. Pro-forma, genre-based, and market-targeted software, hardware, and data shape a significant component of the public's experience with computing in their daily lives.
Case D	Online communities, some website and application development. Significant development in the public understanding of computing has emerged in this case as the availability of Information proliferates.

Table 2. Explicating the Expert-Non-Expert Cases in the Producer/Consumer Relationship for Computing

Aggregations of interest and power likely form about these cases and understanding is also shaped by socialization among and within these groups. From these aggregations come terms like "users" and "IT" and other generalizations that characterize patterns of use in the producer and consumer relationship.

Through the communication channels that surround the groups made possible in the cases shown in Table Two, they are amplified by the personal and philosophical perspectives that also bias and shape language between producers and consumers. "Users" for instance, perhaps in itself arguably a pejorative term, runs a gamut of connotations and is metaphorical at its roots whilst also being a pragmatic descriptor. Other terms embed perspectives and worldviews that potentially run the gamut from objectivist/empiricist to subjectivities / interpretivist, to constructivist and beyond (Falkenberg et al., 1998).

In order to better calibrate our own language and approach to reconciling semantic meaning in computing terms, we can appropriate a previous model used to inform the 1998 Framework of Information Systems Concepts (FRISCO) report from the International Federation for Information Processing (IFIP) Working Group 8.1 on the design and evaluation of information systems (Falkenberg et al., 1998). The report provides a framework used to delineate the concepts that describe how individuals and organizations shape information systems. We appropriate this framework to presume the social context that surrounds communication about computing concepts. Further, we adopt their appropriation of semiotics as a means of describing human communication and the conveyance of meaning. We also assume a systems approach to the interaction amongst computing consumers and producers, such that a system of concepts, models, and language surrounds the communication of computing concepts and terms. Lastly, we adopt the perspective that reflections on this issue are ontological and philosophical in nature.

The FRISCO framework will feature more prominently in our explication of XCCRL, but we first delve further into the complexity of communication by reflecting on Stamper's semiotic framework (1973). Stated simply, Stamper's semiotic framework holds that human communication undergoes several mediated transmissions where translation must happen along these mediated phases. Given human sensorimotor design, humans begin by comprehending and sensing at a physical layer of communication. Our voice and ears utilize physical media as do our written communication, as do our signs. This is empirically sensed and categorized such that the syntax for repeatable comprehension is utilized. The translation from syntax to meaning happens at a semantic layer where validity and veracity are assessed. Sensemaking also involves the application of value and discretion such that we then operate at a pragmatic layer to align dispositions. Later, the manifestation of our reactions and actions in light of the communication operate at a social layer.

Stamper's (1973) semiotic framework can be further comprehended, quite usefully, by grouping the layers into technical (physics, empirics, syntactics) and social (semantics, pragmatics, and social). With these layers we can more closely associate a computing curricular term, such as database, which itself is a composite term, with any and all appropriate layers in the work (Liu, 2000; Stamper, 1973; Stamper et al., 2000).

It is important to recognize that these layers in a communication are both coextensive and amalgamated where the discernment of the layers is not a natural step for the sender or recipient in a communication.

3. BACKGROUND ON XBRL

In 2009, the Securities and Exchange Commission (SEC) mandated that all public companies adopt XBRL as a means to standardize the exchange, transmission, and reporting of accounting and financial data (SEC, 2009). XBRL is an extension of eXtensible Markup Language (XML). XML is a text-based, hardware-software independent markup language, like Hyper Text Markup Language (HTML), which unlike HTML, allows for undefined tagging by the author to define the document structure. XML is designed for storing, transporting, and sharing data across multiple platforms, thus avoiding the issue of incompatible formatting across computer systems (W3Schools, n.d.). As noted, XML defines a data structure and allows for a standard format for exchanging data (VanLengen, 2010).

XBRL extends XML by providing a standard for the exchange, transmission, and reporting of accounting and financial data based upon established taxonomies such as those developed by XBRL International and in the United States, the Generally Accepted Accounting Principles (U.S. GAAP) XBRL taxonomy. For example, each aspect of a financial report represents a concept. Each concept is then "tagged" with an XBRL element from the taxonomy. The element must then be precisely defined, and attributes assigned. In addition, relationships between the elements must be defined as a way of defining the scope of the overall taxonomy. The result of this process is the creation of a XBRL instance document (Wenger, Thomas, & Babb, 2013). As noted by Debreceny and Farewell (2010), "the principal idea of XBRL is that if every supplier of information speaks a common language of disclosure, by using the same taxonomy, users will be able to use that information in a productive way" (p. 467). There are numerous resources available in the literature which explain and provide detailed instructions for mapping financial statements using XBRL (e.g., Capozzoli & Farewell, 2010; Debreceny & Farewell, 2010; Elam, Wenger, & Williams, 2012; Pinsker, 2004; Peng & Chang, 2010; White, 2010).

Similar to the adoption of XBRL as a standardized reporting format for accounting and financial data, the authors propose the development XCCRL, as mechanisms for standardizing the exchange, transmission, and reporting of curriculum data and computing curriculum data within higher education. In sum, XBRL utilizes taxonomies (e.g., XBRL 2004-1; XBRL 2004-2) which define accounting and financial concepts by which a financial instance document is created by tagging the document using software developed for this purpose (e.g., DragonTag). The document can then be transmitted electronically as well as be compared to other financial instance documents. XBRL and XCCRL work in similar fashions only instead of tagging an accounting or financial document, a curriculum document (e.g., a course description) is tagged to create a curriculum instance document. The taxonomy used may be from a recognized computing organization such as the Association of Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), the or Education Special Interest Group (EDSIG).

The history of computing curricula is well established and the development of model curriculum for the areas of computing is ongoing as demonstrated by the works of computing organizations such as the ACM, Association for Information Systems (AIS), AITP-EDSIG, and IEEE. As such, taxonomies have been published in an effort to classify the areas (concepts, categories, knowledge areas) commonly identified in the computing disciplines (ACM, 2012; IEEE, 2017). In spite of the tremendous time and effort put into the development of computing curricula, higher education suffers from the same fate as that of the accounting and financial sector, which necessitated the development of XBRL, namely the challenge of storing, transferring, and sharing of data due to incompatibilities caused by language, type, culture, and location. Ergo, there is no standard reporting format for the exchange, transmission, and reporting of curriculum data.

4. EXAMPLES FROM BOTH DOMAINS

Perhaps, the best way to demonstrate the extension of XCCRL from XBRL is a simple illustration from both domains. Concepts such as "asset", "liability", "owner's equity", "revenue" and "expenses" are well established in the financial and accounting domain. With XBRL, these concepts have been formalized and are now represented in a taxonomy. As mentioned previously, The U.S. GAAP XBRL Taxonomy, which consists of over 12,000 terms, is a standard among U.S. companies. So, consider that a company needs to map its statement of financial position to the U.S. GAAP XBRL Taxonomy. Debreceny and Farewell (2010) provide a mapping process for this task which includes major steps such as: reviewing the accounting concept and searching the taxonomy for corresponding concept. Smaller steps directly related to the financial and accounting sector occur along the way, but the basic premise is to take the accounting concept contained on the statement of financial position and tagging it with the corresponding concept from the taxonomy. For example, the taxonomy includes a node for Statement of Financial Position, Classified. This node can be expanded to display the Assets node followed by the Assets, Current node, Receivables, Net, Current node and so forth. Using software specifically developed for creating XBRL instance documents, the user can then apply the concept from the taxonomy to the associated concept on the statement of financial position, thus creating an electronic document which can be stored, transmitted, and compared.

For the higher education domain for curriculum data, such concepts as "course prefix", "course number", "course description", "course prerequisites", "credit hours", "knowledge outcomes", and "skill outcomes" are familiar concepts. However, depending upon the type, location, culture, and or category of university, college, or school, there may not be a common "language" or standard for storing, transferring, or comparing these concepts. This is where XCCRL comes into play. By using an established taxonomy such as those developed by ACM (2012) or IEEE (2017), it would be possible to tag the concepts of curriculum data with the appropriate concepts from the taxonomy. For example, the ACM taxonomy contains a categorization for Information Systems. Within this categorization, there are multiple sub-categorizations, such as Data management systems, Information storage systems, Information systems applications, and so forth. For the purposes of illustration, the Data management systems category is utilized, specifically the sub-category entitled, Database design and models. The taxonomical hierarchy is provided below:

- Data management systems
  - Database design and models
  - Relational database model
  - Entity relationship models
  - Graph-based database models
    - Hierarchical data models
    - Network data models
  - Physical data models
  - Data model extensions
    - Semi-structured data
    - Data streams
    - Data provenance
    - Incomplete data
    - Temporal data
    - Uncertainty
    - Inconsistent data

To further the illustration, consider a course entitled, Database Theory and Practice and its accompanying course description:

Database concepts and structures. File and data management principles underlying database construction. Fundamental types of database models, with emphasis on relational database as well as on major non-relational forms. Practice in analysis, design, development, and optimization of working database applications on a variety of problems. Small and large system databases will be considered. Prerequiste: BCIS 3332 or BCIS 3333 or approval of department head.

Utilizing the ACM taxonomy categorization Data management systems, the course description can be tagged to create an XCCRL instance document. For instance, 'relational database' from the course description might be tagged with the 'Relational database model' and 'Entity relationship models' concepts from the taxonomy, while 'non-relational forms' might be tagged with 'Graph-based database models' from the taxonomy. This XCCRL instance document could then be exchanged with others and compared against other database courses.

5. A BRIEF ELABORATION ON XBRL

In essence, XBRL predicates on a few simple concepts designed to answer a fundamental question: are these two things comparable? From a metadata and taxonomic standpoint, XBRL is a fairly straight-forward approach and is similar to the keyword tagging that allows to commonly associate concepts and words. Therefore, a given financial concept or phenomena is captured as an XBRL instance such that the associated metadata and taxonomies may convey clear semantic intention. An XBRL instance contains a Discoverable Taxonomy Set which defines the facts of the instance and how these facts should be relatable to other facts. For instance, if an item or tuple used to articulate a business fact should be compared to similar facts, then the context of this fact is stated and the units for relatability are also stated. Figure 1 shows an example XBRL taxonomy:

```
<element
   name="Land"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
<element
   name="BuildingsNet"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
<element
   name="FurnitureAndFixturesNet"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
```

Figure 7. XBRL Taxonomy Snippet

The key to comparability and relatability among XBRL instances is the linked XBLR Taxonomy. The Taxonomy suggests the relationships possible and other identifying attributes that allow one XBML Entity to be relatable to another. The set of additional and related concepts to clarify an XBML instance are established as links of items and tuples that contain substantiating information to serve as the basis of relations. Figure 2 shows associated XBRL Instance entities.

```
  <!--  Units  -->
▼<unit id="U-Monetary">
    <measure>iso4217:USD</measure>
  </unit>
  <!--  Fact values  -->
  <HelloWorld:Land contextRef="I-2007" unitRef="U-Monetary" decimals="
  <HelloWorld:Land contextRef="I-2006" unitRef="U-Monetary" decimals="
  <HelloWorld:BuildingsNet contextRef="I-2007" unitRef="U-Monetary" de
  <HelloWorld:BuildingsNet contextRef="I-2006" unitRef="U-Monetary" de
  <HelloWorld:FurnitureAndFixturesNet contextRef="I-2007" unitRef="U-M
  <HelloWorld:FurnitureAndFixturesNet contextRef="I-2006" unitRef="U-M
  <HelloWorld:ComputerEquipmentNet contextRef="I-2007" unitRef="U-Mone
  <HelloWorld:ComputerEquipmentNet contextRef="I-2006" unitRef="U-Mone
  <HelloWorld:OtherPropertyPlantAndEquipmentNet contextRef="I-2007" un
  <HelloWorld:OtherPropertyPlantAndEquipmentNet contextRef="I-2006" un
  <HelloWorld:PropertyPlantAndEquipmentNet contextRef="I-2007" unitRef
  <HelloWorld:PropertyPlantAndEquipmentNet contextRef="I-2006" unitRef
</xbrl>
```

Figure 8. XBRL Instance Entities

To best extend the XBRL concept, some alignment with the premises of XBRL is necessary. The XBRL Concept is implemented as an XML Schema and these concepts become the basis of the XBRL Taxonomy. The Concept or Concepts contained in an XBRL Taxonomy are extended with one or more Linkbase entities which provide the extended links that make relations possible. Further, the XBRL Instance presents the values particular to fact or facts relevant to a given context. This makes the XBRL Taxonomy and XBRL Instance relate much as a Class and Object relate in Object-Oriented Programming. Figure 3 below illustrates the major elements of XBRL.

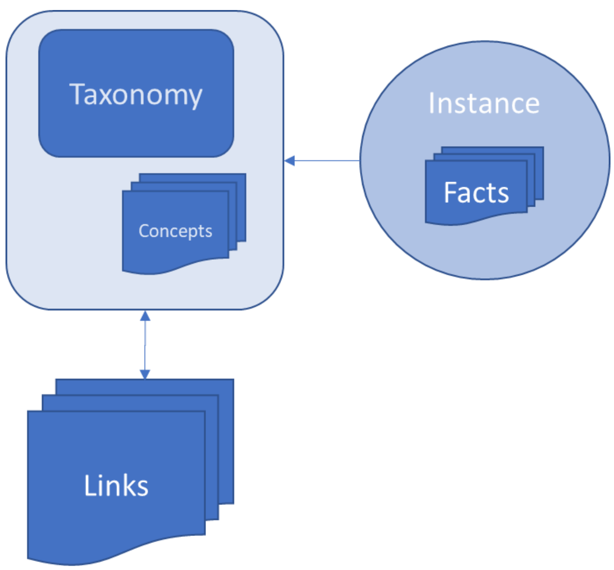

Figure 9. Elements of XBRL

The design of XBRL was to facilitate comparability to standardize meaning in the reporting of financial data, in this regard it holds promise as the basis for a similar approach to reconciling meaning for computing terms as they would inform computing curricula.

6. A SEMIOTIC FRAMEWORK FOR XCCRL

With a high degree of inspiration and direction from the IFIP 8.1 FRISCO report and its semiotic framework to distill and articulate information systems concepts, we extend that work to inform a candidate set of taxonomic structures for XCCRL that may be guided by the assumptions of Stamper's (1973) semiotic framework. Much as the FRISCO report proposed a semiotic-layered accounting for a given information systems term, we extend to account for computing terms in general recognizing that reconciliation at the various semiotic layers holds promise for aligning and mapping terms along and across these boundaries. Recall still that, much as was the case with XBRL, we are looking to align "dialects" across semiotic layers, but, unlike XBRL, we are also attempting to account for commonalities among the layers in a vertical manner.

Semiotic Layer	Question	Answer
Impetus: personal or organizational value	Why do we include database?	Databases track and relate organizational data
Social	What is the context for the concept's use?	Business
Pragmatic	What about this context is important	Transactional data tracking performance
Semantic	What aspects of performance matter?	Sales, Costs, and Profits
Syntactical	How do we represent these?	Models expressed in language that ties back to operations
Empirical	What do we measure?	Identified fields of specific nomenclature
Physical	How do we measure?	Data transmissions from POS systems

Table 3. An Illustration of Semantic Reasoning

Table 3 appropriates the FRISCO report to reason about how a term like "database" has meaning and value in a curricular communication:

From the FRISCO report we realize that a semiotic analysis of any computing curricular concept and term can be derived from the organizational "why" to the technical "how" such that a cogent rationale is maintained. Thus, the following construction is possible (Falkenberg et al., 1998):

> organization - which might be regarded as a
> system - for which different directions and aims are set, as
> goals - towards which the organization strives in order to create
> added value - which normally is accomplished by coherent
> actions - using certain
> resources - meaning that these actions are performed by
> actors – on
> actands - and where these actions are aiming at changing the
> state - within or external to the organization in a desired way

As an analytical technique, the above treatment may not appropriately match all computing curricular concepts, but its structure, informed by semiotics, provides a starting point that is consistent with the XBRL specification.

7. THE IMPETUS FOR XCCRL

The impetus for XCCRL lies with the efforts of the ACM and IEEE inventory and forecast of computing curricula development, Computing Curricula 2020. (See www.cc2020.net.) Directly, the impetus for XCCRL lies within a proposed framework for curriculum description that incorporates and normalizes the structure and intra-connectivity of computing theory and practice (Waguespack and Babb, 2019). The framework underlies a key CC2020 project goal to design a visualization tool capable of both representing and comparing computing guidelines and programs to inform and advance computing education.

The tool specifically focuses on the sub-disciplines of computing at the baccalaureate level and the various prior ACM and IEEE curriculum guidelines: Computer Engineering (2004, 2016), Computer Science (2001, 2008, 2013), Information Systems (1997, 2002, 2006, 2010), Information Technology (2008, 2017), Software Engineering (2004, 2014), and Cybersecurity (2017). (All guidelines are available at www.acm.org/education/curricula-recommendations.).

As the CC2020 effort progresses, the tooling for curriculum visualization has coalesced around the Competency, Disposition, Knowledge, Skill, Task (CDKST) framework that describes the interrelation between these aspects of curricular design, development, and articulation.

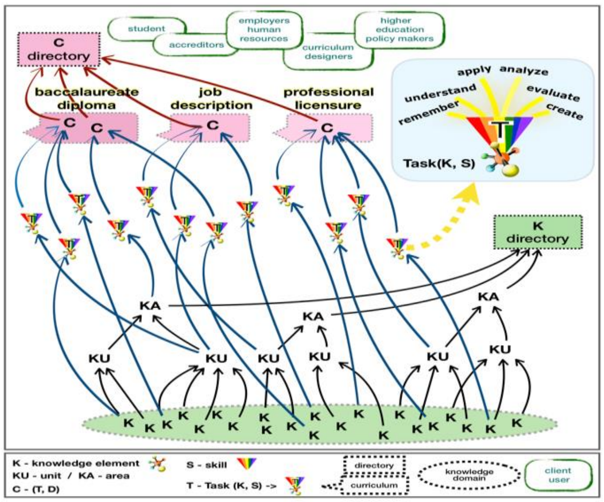

Figure 10. CDKST Curriculum Framework
Appendix B recounts the set-theoretic model devised to support digitization. Figure 4 graphically depicts, and Table 4 summarizes that model, both adapted from (Waguespack & Babb, 2019).

C {competency, demonstrable capability}
D {desired value result, disposition "why"}
K {knowledge, "what"}
S {skilled application of knowledge "how"}
T {task, as situated context of is a situated

T = task
T --> {(Ki,Sj)} knowledge used at a level of skill
[A task is skillfully applied knowledge engaged in a purposeful act.]

C = competency
C --> {(Σ(Ki,Sj) | (Ki,Sj) ∊ T), Dk}
[Competency demonstrates task(s)
in accord / compliant with disposition(s).]

E = educational program
E --> {Ci}
[An educational program is the cumulation of competencies that comprise it.]

B = baccalaureate degree
Be --> {Σ(Ci) | Ci ∊ E}
[A baccalaureate is the cumulation of the assessments of constituting education program.]

J = job description
J --> {Ci}
[A job description is the cumulation of competencies defining that job's responsibilities.]

JP = job permit
JPj --> {Σ(Ci) | Ci ∊ J}
[A job permit is the cumulation of competencies
assessed that certify job competency.]

P = profession
P --> {Ji}
[A profession is the cumulation of job competencies that define it.]

L = professional license
Lp --> {Σ(Ji) | Ji ∊ P}
[A professional license is the cumulation of assessed job competency that certifies professional status.]

Table 4. CDKST Curriculum Framework

8. MOVING FORWARD WITH CC2020 AND XCCRL

A key to appropriating the design and intent of XBRL for XCCRL would be to understand its object-oriented design as the basis for relations. The basis for the visualization project in CC2020 for computing curricula are competencies, dispositions, knowledge, skills, and tasks. These almost align with the semiotic "ladder" that runs from the physical to the social realm as shown in Figure 5 (Falkenberg et al., 1998):

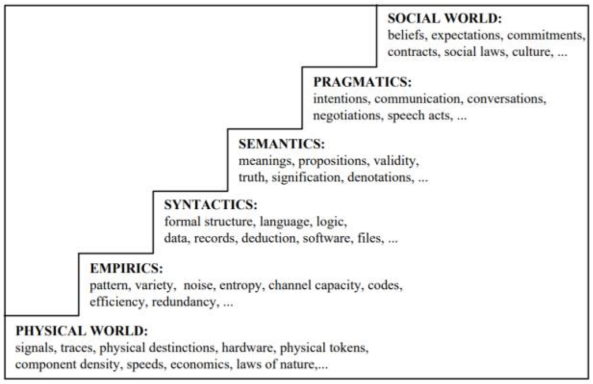

Figure 11. From the physical to the social realm on the semiotic "ladder"

Attempting to relate these, we can align the basic components with XBRL with the elements of the CDKST model to delineate a possible direction for the appropriation of XBRL's design.

XBRL Concept	CDKST Concept	Semiotic Level
Taxonomy	Competency	Social World
	Disposition	Pragmatics
Concept	Knowledge	Semantics
Instance	Skill	Syntactics and Empirics
Units	Task	Empirics and Physical Realm

Table 5. Comparing XBRL Concepts to CDKST Concepts and Semiotic

As we can see, the concepts do not cleanly map and we address this as a shortcoming in the following section. However, the mapping to the semiotic levels is plausible and the XBRL has proven to be successful in reaching its design aims such that it does facilitate successful financial reporting across problem domains, business sectors, and regulatory boundaries.

However, a deeper point of comparison would be to compare the elements of the FRISCO framework with XBRL's key concepts as they relate to the Semiotic levels. Table 6 shows select elements of the key terms that define XBRL along with those of the FRISCO framework to determine whether the FRISCO framework, as a tool designed to reconcile key information systems terms, holds promise for the design of XCCRL (see Table 6).

XBRL	FRISCO	Semiotic Level
Context	Organization Social System System Goal	Organization
Taxonomy Concept	Conception Intention Rule	Social World
Entity	Actor Decision	Pragmatics
Resource	Action Resource Effect Model	Semantics
Instance	Protocol	Syntactics
Fact	Observation State	Empirics
Item	Pattern	Physical World

Table 6. Comparing XBRL Concepts to FRISCO Framework Concepts and Semiotic Level

The FRISCO elements would likely serve at multiple levels but also suggest some consistency with the XBRL organization.

It is likely that the FRISCO framework's language could serve as the descriptors necessary to further elaborate the Taxonomy that would clarify, through linked resources and metadata, the Competency, Disposition and Knowledge that constitute the social dimension of the CDKST model. Further, the CDKST framework is a broad-level means of articulating the wider structure for data collection. We find that XBRL design approach is promising as a design referent for XCCRL. The ontological, philosophical, and epistemological grounding of the FRISCO report is equally informative to serve as the basis for our design.

The nascent architecture for our work is shown in Appendix A. The curriculum object store would likely contain a structure that is similar to and derivative of the XBRL Instance. Further, the computer terms taxonomy would be developed in a manner like XBRL taxonomies. Other aspect of our design includes the collection of curricular texts to assimilate in an overarching taxonomic store. The categorization of concepts (as the serve as the basis of competencies and dispositions) would constitute relations between computing concepts and concepts from related domains. The translation of these curricular inputs will be obtained from text processing using the natural language toolkit for Python (or a similar toolset). The categorization will be accomplished via both an expert system as well as a machine learning component using TensorFlow and/or SciKit-learn. The piece of our architectural puzzle that XBRL addresses is the need for a standards-based (in this case XML) storage and interchange format such that any curriculum object is relatable, mutable, and transferrable. Further, other XML-related technologies increase the likelihood that the visualization engine may directly use items from the curriculum object store without further translation.

9. LIMITATIONS, DISCUSSION, AND CONCLUSION

Among the limitations of the XCCRL concept is the different contexts of curriculum versus XBRL's financial data orientation. Further, the use of FRISCO as the basis of organizing Computing Concepts is the skewness in its business and organizational orientation.

Further, none of the prototypes developed thus far demonstrate sufficient maturity to ensure that the proposed architecture is viable. XBRL has many proven use cases and instantiations suggesting that starting from a reference implementation would be ideal. Rather, our design did not start with XBRL as a referent and may contain assumptions that are incompatible with XBRL.

These limitations aside, XCCRL shares overall design goals with XBRL. Also, the FRISCO report should support a prototype to articulate the additional metadata and fields required to elaborate the elements of the CDKST framework into the tool described in Appendix A and B.

The CC2020 project has among its aims the development of a tool to assist the designers, developers, administrators, and stakeholders of computing curricula to interact with visualized descriptions of curricula. An XBRL and FRISCO combined approach accelerates the prototyping process and assists in the realization of the CC2020 project's aims and objectives.

10. ACKNOWLEDGMENTS

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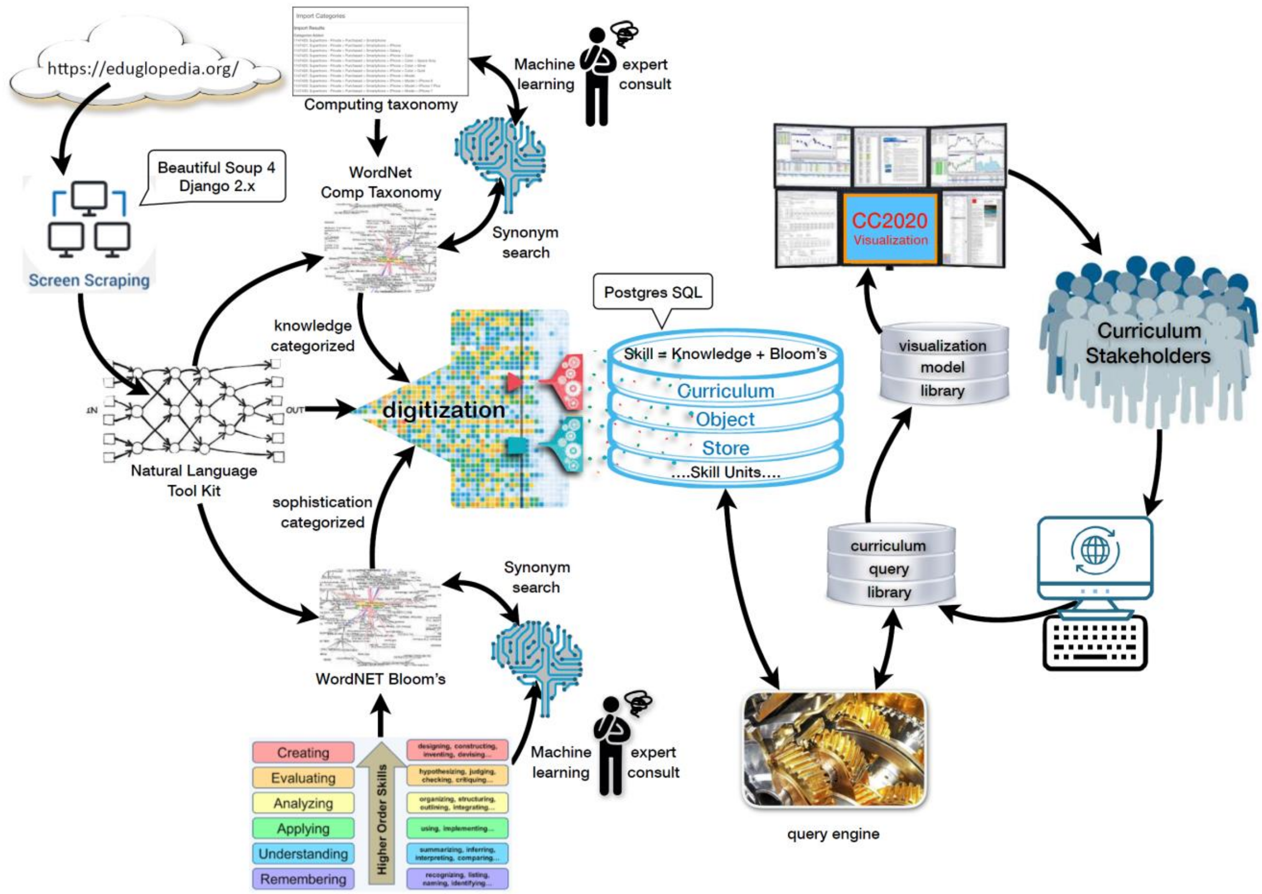
Appendix A – The CC2020 Computing Curriculum Project Tools Architecture and Concept



Appendix B - CDKST Curriculum Framework

Competency-Disposition-Knowledge-Skills-Task

In the following set theoretic representation, *Competency-Disposition-Knowledge-Skills-Task* (CDKST), we adopt three grounding propositions to conceptualize curriculum: 1) learning is acquiring knowledge elements arranged taxonomically that enable satisfactorily performing relevant tasks; 2) the concept of "skill" is a degree of mastery of a knowledge element modulated by disposition to achieve a valued outcome, and 3) disposition denotes the values and motivation that guide applying knowledge while designating the quality of knowing commensurate with a standard of desired performance.

Knowledge elements, **K**, are factual concepts supported by science and/or professional practice that underpin a vocabulary of objects, behaviors, and relationships as the domain of interest in a discourse (be it curriculum, task, job, or profession). **S**, the skill attribute, denotes the *quality of knowing* (e.g. mastery, expertise, adeptness, or proficiency) that an accomplished learner must possess to satisfactorily apply a knowledge element in a circumstance of performance. In this sense it is the capacity to demonstrate a degree of *cognitive command* over that knowledge. In this conceptualization cognitive command is represented by Bloom's (revised) taxonomy of learning objectives: remember, understand, apply, analyze, evaluate, and create (See Appendix A, Anderson, 2001). Disposition, **D**, represents a commitment, motivation, toward an aspect of desired practice that reflects the attitude deemed critical to satisfaction in a circumstance or context. Task, **T**, is a situated instance of engaging knowledge with a degree of mastery. **C**, competency is a demonstrated sufficiency in a task with an appropriate disposition. **C** effective defines both the nature of the competency and the assessment that certifies in a specific task instance.

T = task
T --> $\{(K_i,S_j)\}$ knowledge used at a level of skill

[A task is skillfully applied knowledge engaged in a purposeful act.]

Task, **T**, is *knowledge applied* in a "live" context to accomplish a designated purpose. **T** represents a *specification* of capability that curriculum is obligated to inculcate in the accomplished learner.

A task is the application of specific knowledge to a situation at hand. Note that tasks may be of varying complexity in terms of the range of knowledge elements engaged. Individual knowledge elements may participate in a variety of tasks. A task may be a collection of constituent tasks within which each knowledge element is applied with a distinct skill. As a collective, the task's satisfactory accomplishment demonstrates a sufficiency of knowing and doing.

C = competency
C --> $\{(\Sigma(K_i,S_j) \mid (K_i,S_j) \in T), \{D_k\}\}$

[Competency demonstrates task(s) in accord / compliant with disposition(s).]

Competency, **C**, is the capacity to accomplish a task by applying knowledge and skills framed by one or more dispositions. This is the goal sought by a competency-based perspective on curricular design. This forms a focus for assessment as each competency represents both a requirement and the instrument of certification to assure the learner's successful performance – success denoted by the satisfactory outcome of applying the knowledge in accord or compliant with one or more disposition(s). It is reasonable to expect that a system of competency specifications would form a telescopic or hierarchical arrangement of modularized task complexity and thus, would lead to an incremental or progressive process of learning and experience accumulation that would subsequently justify advancement to more elaborate, intricate, or difficult tasks or higher degrees of desired performance.

E = educational program
$\mathbf{E} \dashrightarrow \{C_i\}$

[An educational program is the cumulation of competencies that comprise it.]

B = baccalaureate degree
$\mathbf{B}_e \text{ --> } \{\sum(C_i) \mid C_i \in E\}$

[A baccalaureate is the cumulation of the assessments of constituting education program.]

E, is a composition of competencies relevant to (or defining) a professional or academic course of study, a curriculum. A baccalaureate degree, **B**, is granted by an authorized institution. In fact, the list of competencies may be the vary testimony to the focus of an intended career direction shaping an academic program's intension. This would be the construct for comparing educational programs, assessing guideline or accreditation compliance, or prototyping distinct perspectives on the larger domain of knowledge such as across subdomains of *computing*!

J = job description
$\mathbf{J} \text{ --> } \{C_i\}$

[A job description is the cumulation of competencies defining that job's responsibilities.]

JP = job permit
$\mathbf{JP}_j \text{ --> } \{\sum(C_i) \mid C_i \in J\}$

[A job permit is the cumulation of competencies assessed that certify job competency.]

In its own fashion, a particular job description is in effect a "mini-curriculum" as it prescribes performance requirements that usually distinguish the desired applicant or employee attributes. The particulars of the organization, the industry, or the marketplace would shape both the collection of knowledge elements, skills, and the disposition of their application, thus, aligning with a particular vocation.

P = profession
$\mathbf{P} \text{ --> } \{J_i\}$

[A profession is the cumulation of job competencies that define it.]

L = professional license
$\mathbf{L}_p \text{ --> } \{\sum(J_i) \mid J_i \in P\}$

[A professional license is the cumulation of assessed job competency that certifies professional status.]

In this last aggregation, professional societies and governmental agencies specify collections of competencies that qualify a legal standing as a licensed professional (e.g. professional engineer, medical doctor, physician's assistant, nurse, a member of the bar, barber, cosmetologist, etc.).

The CDKST model does not attempt to shape or bound the dimensions of pedagogy as that requires integration with the cultural context within which it must be applied. However, pedagogy must align with the designated disposition modulating the *quality of performance* the student must demonstrate as competency in context.

Encouraging Lifelong Learning through Tech Explorations

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Abstract

Information systems tools, techniques, and technologies are changing at an ever-increasing pace. Technical skills with operating systems, applications, and hardware are important to learn in an information systems curriculum so that students can be immediately productive upon graduating, but these skills may have a shelf life. Technical skills (like systems themselves) must be continually maintained, otherwise information systems professionals risk obsolescence. It is imperative that information systems educators provide students with the ability to learn effectively during school and after graduation. Many students struggle to learn independently, preferring instead to have clear learning paths provided for them. To encourage effective lifelong learning, a tech exploration assignment was implemented in an advanced networking security tools course at a midwestern university in the United States. In the assignment, students chose a network security topic according to their interests, developed a learning plan, carried out the learning plan independently, presented their findings, and submitted learning reflections. Results from student surveys showed that despite the challenges of stewarding their own learning process, they found the assignment to be a valuable learning experience that encourages lifelong learning. A detailed description of the assignment, student survey results, instructor observations, and implementation recommendations are provided.

Keywords: pedagogy, technology change, self-directed learning, lifelong learning

1. INTRODUCTION

It is a given that technology will continue to grow and evolve at a rapid pace. Though educators are aware that the specific technology platforms taught in classrooms today will likely be replaced in the future, educators must help students learn skills on these platforms that will be immediately useful upon graduating. Curriculum designers should be forward looking when selecting technologies to teach, but it is hard to predict which technologies society will adopt (Butler, 2016). Therefore, it is imperative that educators prepare students to continue learning after graduation so that students can adapt to change. Skill stagnation is a recipe for obsolescence.

Lifelong learning is important in any field, but especially in information systems because of the high rate of change. According to Caruth (2014, p. 1), "Adult students need to be taught how to learn in order to become lifelong, autonomous learners." Teaching how to learn should be a core part of an information systems degree. Curriculum that focuses too narrowly on specific technical skills may produce graduates that are unable to adapt to industry change (Randall & Zirkle, 2005).

Absent mandates from an employer, professionals have a plethora of options to keep their skills sharp. To keep pace with industry trends, professionals today might pursue skills in data analytics, application containerization, a new programming language, or any of a myriad of technologies that may not have been taught in their degree programs. Some may strive for industry certifications for career advancement or to change roles. In the current work, it is posited that students who are given opportunities to sculpt their learning paths during a degree program will gain confidence in their abilities to learn without explicit direction and will be in a better position to successfully pursue lifelong learning.

Lifelong learning is essential for ensuring that students have sufficient depth in a skill area. Students need both breadth and depth in their educations (Yates et al., 2018). Breadth gives students awareness of a wide range of technologies and skills that can be used to solve business problems. Depth refers to deeper domain-specific knowledge and stronger skills in a given topic. Over recent decades, depth in the field of information systems has increased, possibly due to increased specialization (Ozman, 2007). Instructors can encourage depth in the classroom by helping students learn and apply content independently (Katz, 2018). A learner-centered approach is critical to achieving depth (Manson & Pike, 2014).

In the next section, critical elements of the assessment process that relate to lifelong learning will be explained. Following the literature review is an explanation of a tech exploration assignment that aimed to develop self-learning skills that support lifelong learning.

2. LITERATURE REVIEW

In this paper, lifelong learning refers to continuing education that occurs after students leave academia. Lifelong learning is typically voluntary and self-motivated where the learner drives the learning process rather than an instructor (Department of Education and Science, Dublin (Ireland), 2000). Lifelong learning is frequently self-directed which takes grit--"consistency of interest and perseverance of effort" (Brooks & Seipel, 2018, p. 22). Because learners become their own instructors, they must be equipped with skills to carry out each step of the assessment process.

Assessment Process

The assessment process includes developing learning objectives, ensuring that curriculum is aligned with the objectives, creating a plan to assess objectives, gathering assessment data, then using the data to inform improvements (Allen, 2004). This process is carried out at several levels in academia including the degree level, course level, and individual lesson plan level. The assessment process has strong face validity. It makes sense to plan what students should learn, develop appropriate learning activities, check to see if they learned what they were supposed to, and make improvements based on data.

The assessment process is deceptively simple. There are several reasons why students struggle to implement this process independently. First, the process is not easy to carry out effectively. For example, it is all too easy to draft ambiguous learning objectives, develop curriculum that follows a textbook rather than defined learning objectives, and create subjective grading rubrics. The assessment process requires skills that must be practiced and honed. Second, it is likely that information systems students (like their peers in other business programs) have had little opportunity to implement the process independently. Students constantly participate in learning activities and receive assessment results, but rarely define learning objectives, develop learning activities, create assessment instruments, or reflect on their own learning process. If educators believe in the assessment process, it should be taught as a critical skill for lifelong learning.

Learning Objectives

Learning objectives are the expected outcomes of an academic activity, course, or program. They are often created by defining what knowledge and skills should be acquired by the completion of the learning phase. There are several reasons why information systems students might struggle to create clear learning objectives. First, when exploring a new technology, students may not know how much they might be able to learn in a given timeframe. Second, a topic might be so new that students struggle with precise terminology needed to create clear learning outcomes. Without specific learning objectives, it is hard to find focused resources to meet the objectives or define assessment criteria.

Curriculum Alignment

Learning objectives, methods, and assessments should be aligned for effective learning (Biggs, 2003). The number of curriculum options available to students has increased dramatically in recent years. Many people are putting tutorials online on sites like YouTube and Vimeo. Increasingly, people are going directly to video streaming sites to find information. YouTube is currently the world's second most popular search engine (Richards, 2018). Some people include video content online that complements books, such as the YouTube series "Automate the Boring Stuff with Python" (Sweigart, 2015). In addition, companies are increasingly putting free product training online, such as IBM's Academic Initiative (Gerber, 2015). Vendor-supplied training is a win-win for students and companies—the students have access to educational content and companies train prospective customers. Lastly, there has been an increase in Open Education Resources (OER) such as free textbooks and other training content. In summary, there is a wealth of information available to students online. Taking advantage of this information is a skill that must be developed.

Gathering Assessment Data
Assessments are embedded at different levels in academia. At the program level, ETS Major Field Tests are an example of assessing program-level learning objectives ("The ETS Major Field Tests," n.d.). Examinations are often given to measure course-level learning objectives. Quizzes, essays, and presentations are examples of unit-level assessments that typically receive quantitative grades and potentially qualitative feedback. Informal assessment occurs continuously as educators judge the quality of discussion, engagement, and demonstrated abilities despite no grades being recorded. For lifelong learning, students need to know how to measure whether they have mastered a skill without having a grading rubric provided to them. Evidence suggest that with training, learners can effectively assess their performance (Thawabieh, 2017).

Reflection
Analyzing assessment data is an important part of the learning process. Assessment identifies gaps in knowledge or skills. Students use assessment data to identify their areas of strengths and weaknesses. Educators should use assessment data to inform changes that might be needed in any part of the learning process. Assessment outcomes short of expectations could indicate ambiguous learning objectives, the need for improved curriculum, or problems with the assessment instrument. Continual improvement is only possible when reflection occurs at the end of the assessment process. Reflection allows learners to give themselves feedback which will enhance future learning activities (Thawabieh, 2017).

The remainder of this paper describes and evaluates a tech exploration assignment in which students plan and carry out their individual learning paths under the direction of an instructor. The details of the assignment are given in the next section.

3. TECH EXPLORATION ASSIGNMENT

A tech exploration assignment was introduced in an upper-division information systems course. The assignment had three core learning objectives. First, students would learn relevant topics related to the course objectives, such as network security tools. Second, students would be able to summarize and present findings effectively. Third, and most importantly, students would learn how to implement the assessment process. Students completed four tech exploration assignments during the course to allow them to improve their performance over time.

There were four principal components of the tech exploration assignment: the proposal, following the proposed learning plan, presentation of key findings, and a reflection. These elements were designed to map to the major activities in the assessment process. The individual elements of the tech exploration assignment will be described in detail in the following sections.

Proposal
In the first phase of the tech exploration, students submitted proposals that included their chosen topic, learning objectives, specific resources and activities that would be used to reach the learning objectives, estimates of how long different learning activities would take, and an explanation of how evidence of learning would be documented.

Topics needed to be related to network security, but a great deal of latitude was given to students to make the case that a given topic fell under the umbrella of network security. A list of potential topics was given to students to guide decision making. Example topics included the python programming language, web server configuration, the Ruby on Rails web framework, Metasploit, cloud computing, and information technology governance models. Students were encouraged to pick topics that would make hands-on learning possible.

Students needed to write specific, clear, and measurable learning objectives by defining what new skills and knowledge they would have by the end of the tech exploration. Bloom's taxonomy of educational objectives is a framework that helps educators choose appropriate goals and language when defining learning objectives (Krathwohl, 2002). The taxonomy employs cognitive process dimensions (such as remember, apply, and create) and knowledge dimensions (such as factual knowledge and procedural knowledge). The taxonomy was shared with the class to help identify learning outcomes and provide suggestions for verbs to use. Next, students described how these learning objectives would help them in their careers.

Students identified one or more resources they would use to reach the learning objectives. Points would be deducted if students said they would use "a python tutorial" instead of something more specific like "all of the basic tutorials on learnpython.org." Next, students estimated how much time they would spend carrying out the learning activities using the identified resources. An expectation of 8-10 hours was given as a target for the learning phase of the tech exploration. Lastly, students were asked to define how they would document evidence of learning. The evidence needed to be measurable through screenshots of code snippets they wrote, running websites they developed, online course quiz scores, custom installation guides, or other objective methods.

The grading rubrics for the proposal and other assignment elements are included in the appendix. The proposals were graded within a day of submission to validate the chosen topic and to ensure that the learning plan was well-defined. When a student selected a topic for which the instructor was not an expert, the student was told how much support the instructor would be able to give.

Following the Learning Plan

Once the proposal had been graded, students began following the learning plan. The instructor had less involvement in this phase of the assignment. Because the tech exploration was largely self-directed, the instructor monitored progress informally and helped students with problems as they arose. It was incumbent upon the students to work diligently and be proactive about asking for help in this stage of the assignment. Students were given reminders about upcoming due dates, but the instructor was not the one teaching the content. There was no grade given during this part of the project. This phase lasted 3-4 weeks. Because the bulk of the tech exploration work was done outside of class, in-class time was more devoted to instructor-designed curriculum and activities that supported program learning objectives.

Presentation of Findings

Students presented a summary of their topics to the class at the completion of the learning phase. They were told to present as if trying to convince their hypothetical employers how the topics they learned would be beneficial to their organizations. To prepare students for different presentation scenarios, students were required to use a different presentation method for each of the four tech explorations: a live demonstration, a whiteboard presentation, a slide-supported presentation, and a video. For the live demonstration, students were prohibited from using slides, but were allowed to use the classroom projector to show materials like applications or code. For the whiteboard presentation, students were prohibited from using any technology. The slide-supported presentation looked like a typical PowerPoint-backed presentation. Lastly, students created a video 5 to 8 minutes long that was played during the last day of class. Presentation grades were awarded on the evidence of planning and practicing.

Reflection

Students submitted learning reflections that included a copy of the learning objectives from the proposal, evidence of learning (such as sample code, course completion reports, or installation guides), an evaluation of the learning resources used, the time they spent on each learning activity, and a general reflection about their topic.

Effort during the learning phase of the tech exploration accounted for half of the assignment points. Students were expected to follow the learning plan and adapt to challenges in resourceful ways. Students who simply gave up when learning became difficult received low marks. The remainder of the reflection assignment grade was generally evaluated by assessing completeness and thoughtfulness.

The next section describes how the tech exploration assignment was evaluated by the students.

4. METHODOLOGY

Data was collected at a midwestern university in the United States. The tech exploration assignment was introduced in a capstone information systems course. All 9 students enrolled in the course (8 male, 1 female) completed 4 tech exploration assignments and completed the anonymous survey. No incentives were given for survey participation. The survey included quantitative assessments of various aspects of the assignment as well as qualitative questions that allowed students to provide open-ended feedback.

5. RESULTS

Quantitative and qualitative results from the student survey will be presented. After, instructor observations will be given.

Prompt	Mean	SD
I put more effort into my tech explorations than most college assignments.	2.67	1.87
I enjoyed the freedom to pick my own topic.	2.00	1.66
The instructor provided helpful guidance throughout the project.	1.22	0.44
Because of this assignment, I am more confident in my ability to learn new knowledge and skills after graduating.	1.78	1.30
This assignment will help me pursue lifelong learning.	2.11	1.54
I gained useful skills and knowledge from this assignment.	1.89	0.60
It was useful to learn to present in different formats.	1.33	0.71

Table 7: Overall Assignment Impressions (1=strongly agree, 7=strongly disagree)

Student Survey Analysis

Students rated the degree to which they agreed with statements regarding multiple aspects of the tech exploration assignment. The questions used a 7-point Likert scale with options ranging from strongly agree (1) to strongly disagree (7). The means and standard deviations for each prompt are in Table 7.

Element Difficulty	Mean	SD
Selecting a topic	5.33	1.66
Developing a learning proposal	3.44	1.33
Learning the topic using the resources identified in the proposal	3.67	1.58
Documenting the evidence of learning	3.22	1.79
Presenting a summary of your topic	2.89	1.69
Writing the reflection	2.22	1.48

Table 8: Difficulty of Assignment Elements (1=extremely easy, 7=extremely difficult)

Students rated the difficulty of the major elements of the tech exploration assignment. The questions used a 7-point Likert scale with values ranging from extremely easy (1) to extremely difficult (7). The means and standard deviations are in Table 8.

Students rated the usefulness of the assignment elements using a 7-point Likert scale. The values ranged from extremely useful (1) to extremely useless (7). Table 9 provides the means and standard deviations of perceived usefulness.

Element Usefulness	Mean	SD
Selecting a topic	2.44	1.01
Developing a learning proposal	2.11	1.36
Learning the topic using the resources identified in the proposal	1.56	1.33
Documenting the evidence of learning	2.44	1.74
Presenting a summary of your topic	1.89	1.36
Writing the reflection	2.56	1.51

Table 9: Usefulness of Assignment Elements (1=extremely useful, 7=extremely useless)

Students were asked to provide a preference for the tech exploration assignment compared to other types of assignments. The preference was recorded using a 5-point Likert scale with values ranging from strongly preferring the alternative (-2) to strongly preferring the tech exploration (2). Means and standard deviations are in Table 10. The results indicate that students preferred the tech exploration over reading articles and watching videos. Students preferred group discussions and hands-on labs in class over the tech exploration. The data did not indicate a preference difference compared to class lecture.

Comparison Assignment	Mean	SD
Class lecture	0.00	1.32
Group discussions	-0.78	0.83
Hands-on labs in class	-1.56	0.53
Watching videos	1.11	1.05
Reading articles	1.11	1.17

Table 10: Preference of Assignments (Positive values indicate a preference toward tech explorations.)

Qualitative Feedback

Students were given the opportunity to provide open ended feedback but were not required to provide input. First, students were asked what parts of the assignment they enjoyed. Two students enjoyed presenting their topics to the class. One student enjoyed the struggle of the problem solving. Three students liked the ability to pick topics that specifically interested them.

One student said, "I enjoyed learning at my own pace, but felt aimless at times."

Students were asked to explain the parts of the assignment that were most challenging. Several students mentioned that picking a topic was challenging. The next most common feedback was related to learning objectives. It was difficult to define learning objectives and stick to them.

Students were asked what changes should be made to the assignment to make it a better learning experience. Three of the five students who answered the question said they would not make any changes. One student recommended restricting topic selection to specific themes such as scripting, penetration testing, or cloud computing. One student wanted more flexibility in presentation methods.

Instructor Observations
It was fascinating to observe the topics selected by students. Several students chose topics related to the Raspberry Pi—a compact yet complete computing platform. Students used the Raspberry Pi devices for war walking (with guidance from the instructor on legality), advertisement blocking with the Pi-hole, and more. Some students reportedly spent about 20 hours on a single assignment getting their Raspberry Pi projects working. These projects incorporated operating systems, computer hardware, scripting, network configurations, and lots of troubleshooting which made them appropriate for a capstone information systems course.

Because students were invested in their own topics, they seemed to apply themselves more and dedicate as much time as needed to succeed. Overall, students seemed to work harder outside of class on tech exploration assignments than other types of assignments, such as reading chapters in a textbook.

Students generally appreciated being required to present using different methods. They did well when giving live demonstrations, explanations using a whiteboard, and when supported by slides. They struggled most when required to create a short video. Despite having access to professional software resources in campus media labs (such as Adobe Premiere), most students downloaded video creation software they found from search engines with varying degrees of success. Most students spent several hours learning to do basic video editing.

In the first tech exploration assignment, many students struggled to create specific and measurable learning objectives. In most cases, students were able to proceed with the learning plan despite learning objective ambiguity because the other parts of the learning plan were strong, but in rare instances students were asked to resubmit their proposals with improved learning objectives. Feedback for improvement was given, and the learning objectives improved in the subsequent tech exploration proposals.

Students often went beyond the resources they had identified in the proposals. Help forums and search engines were often used to clarify terms or troubleshoot problems. Students sought these additional resources without any prompting from the instructor and in most cases were able to address their knowledge gaps.

Failure on the assignments happened in a variety of ways. First, some students underestimated how much time it would take to reach the learning objectives. Generally, the first tech exploration of the semester opened students' eyes to the need for better planning. Second, some students tried to merely repeat content from previous classes and did not go into any greater depth. Failure of students to challenge themselves could sometimes be identified when reviewing the learning proposals. However, because much of the learning took place outside of the classroom, lack of effort was sometimes not apparent until the class presentation by which time it was too late for the instructor to make corrections. Lack of effort was evidenced in several ways. Sometimes, students reported their own lack of effort during the presentation to their peers. Other times, students did not fully document their evidence of learning or reported very few hours spent learning using the resources they had identified.

6. DISCUSSION

One concern when designing the tech exploration assignment was that because most learning would happen independently that students would feel unsupported. The results show that students felt supported through the assignment. The perception of support was likely driven by prompt feedback on assignment submissions, help selecting topics, and suggestions on scoping tech explorations appropriately for the time available.

The data support the idea that the tech exploration assignment supports lifelong learning. Students believed that the assignment helped them pursue lifelong learning and gave them skills to do so. While learning how to learn, students also reported learning useful skills and knowledge by completing the assignment.

According to students, the most difficult part of the assignment was picking a topic even though they enjoyed the freedom to pick their own topic. The other elements were rated as moderately difficult, except for writing the reflection which was rated the easiest of all assignment elements. The data suggests that the assignment is appropriately challenging. Learning the chosen topic was reported to be the most useful part of the assignment, but each element of the assignment was rated as useful.

Compared to other assignments, students preferred the tech exploration over reading articles and watching videos. However, they reported a preference for group discussions and hands-on labs in class. A preference for active, participatory learning is seen in the responses. Students may have expressed a preference for in-class labs and group discussions because in those assignments they do not have to select their own topics or create documentation—tech exploration elements that were rated most difficult. In the end, the tech exploration assignment should be seen as a complement and not a replacement for other types of assignments.

Overall, the results suggest that the tech exploration assignment is effective for encouraging lifelong learning, allowing students to dig deeper into topics of interest, developing presentation skills, and improving technical skills.

Suggestions for Implementation

Timely feedback is important for assignment submissions because students only have approximately three weeks after the learning proposal submission to complete all learning activities. If changes need to be made to the learning plans, students need to know quickly so that they can adjust their plans accordingly.

It is important to let students know the degree to which the instructor can help with the topic. For example, if the student wants to learn Django and the instructor has significant web development experience, it is likely that the instructor can give guidance and help troubleshoot if the student hits a roadblock. Students should be aware when the topic chosen is outside of the instructor's area of expertise and will be less able to give helpful direction. Despite my own inexperience with the Raspberry Pi, I was able to help students find appropriate resources and solve problems. According to the survey results, students felt supported by the instructor despite lack of experience with every chosen topic.

Students must be held accountable for the quality of their work. While most students embraced these tech explorations to dig deep into a topic, some students tried to set learning objectives that did not push their learning far enough. Detailed grading rubrics can help set expectations for effort and provide an objective way to evaluate performance.

The tech exploration assignment was given in a capstone course of an undergraduate program. By this point in their academic careers, students had mastered information systems fundamentals and proven that they could use technology with less direction. It is less likely that this assignment would have been as successful in an introductory course. In some tech explorations, students created virtual machines, connected to servers using SSH, installed programming runtimes, and carried out similar tasks. These were tasks for which students had been prepared in previous courses.

If requiring students to create videos, tutorials should be developed that address common video requirements. Step-by-step instructions to create a video that combines clips from screen recording software and cell phone video would have helped students learn the majority of skills necessary for the tech exploration. Having mastered these basic techniques, students could spend more time producing content rather than learning video creation software.

Though the tech exploration assignment evaluated in the present work was given in a low enrollment course, the assignment could scale to larger classes. Only the presentation of findings would need adjustment to accommodate a large number of students. In high enrollment courses, presentation lengths could be shortened, students could present to peers in small groups, or students could be required to submit video presentations for each tech exploration.

Limitations

The sample size of this study was relatively low and there was no control group. True evaluation of the effectiveness of this assignment for supporting lifelong learning could only be done by evaluating student learning effectiveness after graduating. Periodic follow-up surveys would be necessary for ensuring that students continue to apply the formal learning process when pursuing new knowledge and skills after graduating.

7. CONCLUSIONS

Information technology changes rapidly and it is a challenge to keep skills current. In addition to assignments that include learning objectives for state-of-the-art technology, educators should ensure that students develop learning skills to facilitate lifelong learning. Despite having spent many years in school, students must be taught how to learn. Tech exploration assignments appear to be effective for teaching students how to learn.

Tech exploration assignments require students to choose a topic to study, develop a learning plan, follow the learning plan, document their evidence of learning, present findings, and reflect on the learning process. These assignments help students develop specific technical skills while helping them develop lifelong learning skills. It would be most appropriate to implement this type of assignment in upper division courses because students will have already developed strong technical foundations.

Instructors implementing these assignments should provide clear grading rubrics with expectations for performance. Prompt feedback should be given to ensure that students have time to make corrections to their learning path as early as possible. Instructors should be open with students about their areas of expertise and the extent to which they can provide support for the students' chosen topics. Overall, the tech exploration assignment complements other learning activities well.

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Appendices and Annexures

The following grading rubrics were used to evaluate the tech exploration assignments.

Proposal Grading Rubric

	None	Below Expectation	Meets Expectation
Learning Objectives	0: None included	2: Vague and no application to career included	4: Clear and application to career included
Resources	0: None identified	2: Not specific (e.g. no URL, book name)	4: Specific resources identified
Time Estimation	0: No evaluation of resources or time included		2: Included
Evidence of Learning	0: Not included	3: Included, but unspecific	5: Clear, measurable evidence identified
		Total	15

Presentation Grading Rubric

	None	Below Expectation	Meets Expectation
Focus	0: No information shared	5: Information presented without a common thread	10: Clear presentation purpose
Polish	0: Unpracticed, sloppy	5: Some effort to prepare, but lacks polish	10: Evidence of rehearsal, free of mistakes, enthusiastic
		Total	20

Reflection Grading Rubric

	None	Below Expectation	Meets Expectation
Overall Effort	0: No attempt to follow the learning plan	10: Began following the learning plan but gave up when obstacles encountered	20: Followed the learning plan thoroughly or adapted to challenges in a resourceful way
Evidence of Learning	0: No evidence provided	5: Some evidence of learning provided, but not enough to validate the learning objectives	10: Evidence supports the completion of the learning objectives
Resource Evaluation and Time	0: No evaluation of resources or time included	2: Vague description of resources and time spent	5: Thoughtful assessment of resources and a breakdown of time spent
Summary	0: No summary included	2: Vague assessment included	5: Assessment shows thought about application in the field of information systems
		Total	40

The impact of an interactive textbook in a beginning programming course

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Abstract

Online textbooks allow instructors to provide interactive and engaging activities for students. In this paper, we look at how providing an interactive online textbook is utilized and valued in a beginning computer programming course. In addition, we compare the utilization of the online textbook to the student final course grade. Our findings suggest that students would rather use an online textbook and the level of engagement in the online textbook activities was positively related to a student's final course grade. These findings encourage us to continue evolving and improving the interactive features provided in the online textbook.

Keywords: online textbooks, interactive textbooks, active learning, computer programming

1. INTRODUCTION

Advances in technology afford new ways for students to learn. For example, today's students are more comfortable using online sources and the availability of free learning resources such as Codeacademy and Khan Academy have changed the education landscape. Educators looking for ways to improve student learning and engagement have developed online resources, including online textbooks to help students learn computer programming.

The hope is that an interactive online textbook may be more appealing to students, thus increasing their use of the resource. Current research shows that many students do not read textbooks as assigned. Reasons include poor study habits, lack of motivation, and poor time management (Starcher & Proffitt, 2011). Some students do not even have the textbook due to the high price (Robinson, 2010). Brost and Bradley (2006) found that students may not read the textbook because they know the teacher will cover the material in class anyway.

We sought to answer three research questions in this study. One, what classroom activities and assignments do the students view as valuable? Two, how do the students perceive the usefulness of the online textbook readings, activities, and quizzes? Three, is a student's online textbook grade indicating their participation and effort in the online textbook a valid predictor for the overall course grade?

This paper begins with a literature review related to interactive textbooks. Then the development of our online tool is discussed along with the format of the course and implementation details of the new tool. Results from student surveys and data analysis to answer the research questions are then shared.

2. LITERATURE REVIEW

The pedagogical rationale for this study was based on active learning defined as activities that encourage students to engage with course materials and increase critical thinking (Lumpkin, Achen, & Dodd, 2015). Many studies have found that students like active learning as well as discovering that students can retain content better (Hyun, Ediger, & Lee, 2017). The use of an interactive textbook requires students to be actively involved in their learning experience. The majority of the literature surrounding interactive, online textbook resources in computer science education from the last ten years seems to be concerned with the analysis of student improvement in related courses. Other studies have focused on student perceptions and usage of online textbooks, and some have centered on effective design components of such a resource.

The research that evaluates student improvement when using an interactive resource varies in sample size and thoroughness, but much of it seems to agree in finding positive correlations. Aldubaisi (2014) examined computer science student performance in conjunction with the use of an interactive e-textbook, one apparently developed for the study by the author. Although this was a short-term study, it resulted in a positive reaction and better performance from the students who participated. Edgcomb et al. (2015) embarked on a long-term, thorough study across three universities, four programming classes, and almost 2,000 students for multiple terms (same instructors). They found significant statistical improvement in both exam scores and final letter grades, when comparing users of an interactive text versus a static one. A pilot study by Farnqvist, Heintz, Lambrix, Mannila, and Wang (2016) involved an online tool called OpenDSA, used for data structures and algorithms courses. Their main finding was that students scored better on the final exam, while also showing a preference for the online tool in log data and questionnaires. A study by Alshammari and Pivkina (2017) compared discrete math and programming courses, in terms of early versus late completion of interactive reading assignments and student performance. Notably, they found that early finishers of interactive reading did better in discrete math, but there was no significant improvement for the analogous programming students; however, the authors concluded that another factor may have to do with how essential the assigned reading is to the course in question.

Studies that mainly investigate student perceptions of interactive textbook material seemed to concur that feedback is generally positive and usage is increasing. Warner, Doorenbos, Miller, and Guo (2015) did a quantitative study of an interactive, online computer programming text using data gathered from over 43,000 users. They found that all types of students (high school, college, online only) used the interactive components extensively, and many used the resource by jumping around, rather than just sequentially. Research by Pollari-Malmi, Guerra, Brusilovsky, Malmi, and Sirkia (2017) focusing on a Python course in Finland found that there was better student motivation, learning, and feedback regarding interactive texts versus static texts. The authors noted that other differences in teaching methods could have also contributed to the results, but any effect was deemed to be small. In addition, there was a flipped classroom study by Davenport (2018) that involved computer programming tutorials in a meteorology course. Although earlier studies suggested negative perceptions of this flipped methodology (including the interactive resources), especially toward the end of the semester, this particular study related to computer programming found that the majority of students recognized the benefits.

Finally, the design studies each offered suggestions for effective interactive components, but from different perspectives. The resource presented by Way (2016) was an interactive Java programming text and was presented in a self-justified manner. Notable design elements advocated by the author included active links to content, interactive coding, animations, and quiz-like checkpoints. In contrast, Ericson, Roger, Parker, Morrison, and Guzdial (2016) offered a well-tested and developed design study, built upon previous studies by the same authors, which included different iterations of the interactive text, as well as teacher and student observations and experiments. The major design recommendations proposed included combining worked examples, practice, and exercises at the end of chapters. Given the interest in studying interactive textbooks and their positive impact on students, we decided to explore creating our own interactive resource.

3. COURSE DEVELOPMENT & DELIVERY

At this institution, the first foundational programming classes are taught in a sequence of three courses: Computer Programming I, Computer Programming II, and Data Structures. The Computer Programming I course is an introductory course currently taught in Python that covers basic programming concepts including types and operators, control structures, files, functions, and classes. A committee of faculty in the School of Computer Science and Information Systems (CS/IS) determine these topics.

In previous semesters, the course content was delivered using PowerPoint notes, text-based exercises, and projects that were provided through the course management system. The instructors utilized the PowerPoint notes to cover the programming concepts. The text-based exercises and projects were then completed by the students and submitted for grading. In addition, students were provided a printed textbook as a secondary resource.

In this course format, the provided printed textbook was not required to be utilized by students because it was not integrated into the course materials. Students could utilize it to read additional information on a topic or see other code examples, but there were no assigned readings or assignments from it. The main reason for this was that the textbook contained more information and topics than what was covered in the course. In addition, the concepts were introduced in a different sequence from the order in which the course was organized. The instructors determined that they wanted to provide the students with a textbook that covered only the topics the course introduced and in the sequence in which they were covered. At the same time, they wanted to create engaging components that would enrich the content and give students opportunities to practice the concepts. These factors motivated the instructors' desire to create an online interactive textbook that would do the following: 1. Incorporate the topics in the sequence introduced for this course. 2. Provide students immediate feedback when practicing basic programming concepts to help prepare for quizzes and exams. 3. Give students with different learning styles and/or disabilities access to online assistive technologies.

The online textbook was created in three phases. The first phase was to create the content. Following the outline and sequence of topics previously used in the course, the instructors divided the topics into seven chapters. Chapters were then separated into pages. Each page was then constructed into numbered sections that covered subgroups of the chapter topics. An example of a chapter outline follows.

Chapter 1
- Page 1
  - I. Intro
  - II. Output/Comments
  - III. Identifiers/Data Types
- Page 2
  - IV. Numeric Data
  - V. Input
  - VI. Turtle Graphics

The sections included interactive activities, which allowed students to check their understanding of the content covered in that section and receive immediate feedback. These activities ranged in format from multiple choice, fill in the blank, and matching questions. The sections also included what the instructors called an interactive code writer, which is an Integrated Development Environment (IDE) that has predefined code examples in it. Students can run, modify, and write code directly in the code writer. This gave them the ability to observe how the code executes and to view how modifications to the code affected the output. At the end of each page, a quiz was available for the students to test their knowledge of the topics covered.

During the next phase, the publisher and the instructors worked together to review all content and test all interactive units to make sure they functioned correctly. A small scale usability test was then conducted with a student who had previously taken the course. They provided feedback as to navigation and ease of use of the online textbook. The last phase was implementation of the online textbook during the spring 2019 semester. All sections of the course offered during that semester utilized the online textbook. There was not a control group because our school requires the use of the same textbook for all sections of a course.

The instructors introduced the online textbook the first day of class. Students then set up their account within the online textbook using the access code given to them by the instructor. Instructors familiarized students with the navigation of the online textbook and how to work through the interactive components. Students were expected to work through the content in the online textbook prior to class and to practice the concepts. Students were instructed that none of the activities would be graded but were encouraged to use the content and activities to help them prepare for class, quizzes, and exams.

During class, instructors created code examples in Thonny, the IDE used in this class, and traced examples on the board to reinforce the concepts the students completed in the online textbook. Most class periods began with a short daily practice problem. Outside of class, students worked on longer module programming projects, worksheets, and short coding problems in a discussion format.

4. DATA ANALYSIS

The instructors gave an optional anonymous survey at midterm to gather data regarding the online textbook, course assignments, and in-class activities. The students were also asked open-ended questions regarding what they liked and did not like about both the online textbook and the class in general. Giving the first survey at midterm allowed the instructors to address concerns and make adjustments during the semester. Forty students took the midterm survey. The majority of the students who enroll in the course are freshman computer science majors but other majors also take the class including GIS, math, and digital media.

	Instructor 1 (n = 25)		Instructor 2 (n = 15)		df = 38	
	M	*SD*	*M*	*SD*	*t*	*p*
Project	4.12	1.2	4.27	.70	-.43	.670
Wkshts	3.96	1.0	3.80	1.0	.48	.633
Discuss	3.88	.88	3.87	1.1	.04	.966
Quiz	3.88	1.0	3.53	1.5	.82	.420
Videos	3.24	1.8	3.33	1.7	-.16	,873
Daily prac.	4.16	.85	4.20	1.1	-.13	.897
Thonny demos	4.68	.63	4.67	.62	.07	.948
Tracing	4.48	.77	4.13	.83	1.34	.189

Table 1: Differences between instructors

To answer the first research question, the students were asked at midterm to assign a score (1-5 with 5 being the best) to each class component. There was a choice "have not used" to select if they had not used that component. Data analysis was done to see if there were any differences in the class components between the two instructors. The independent samples t-tests indicated no significant differences between instructors so the students were combined into one sample for the remaining tests. Table 1 shows the results of these t-tests.

Table 2 shows the mean midterm scores for each component as rated by the students. Overall, the scores were positive with higher numbers associated with the activities that were done during class time and the programming projects done mostly outside of class. All components of the course, the online textbook, assessments, projects, discussions, and worksheets were closely related and covered the same material in different ways. This was possible since the course instructors wrote the online textbook.

Class Component	Mean 1-5 scale n = 40
Module programming projects	4.18
Worksheets	3.90
Discussion coding problems	3.88
Quizzes given in class	3.75
Lightboard tracing videos	3.28
Daily practice problems	4.18
Class demonstrations in Thonny	4.68
Tracing on whiteboard in class	4.35

Table 2: Mean scores of class components at midterm

Students had the option to share comments about what they liked about class and what they would like to have changed. The answers to these questions were analyzed to determine the most frequent comments. The most prevalent remark was to continue with the coding examples in Thonny. Since the instructors were no longer using PowerPoint lectures to cover the material, they often went into the IDE and typed Python code and comments and had the students follow along with them. The next two most frequent comments were to keep doing the module programming projects and the daily practice. The module programming projects were larger assignments that were completed mostly outside of class while the daily practice worksheets were like what many call bell work as they were handed out at the beginning of the class and the students were given the first 5-10 minutes to complete the worksheet which required them to predict code output or write code. The teachers would then review the daily practice before continuing class, and the students got to keep the sheet. These were not graded. The comments about what to change included "more examples in Thonny" and "more complex in-class assignments." Clearly going through code in the IDE in class was viewed as valuable to students.

The students were also asked at midterm how much time they spent with the online textbook each week. We did not have the students keep a reading log so it was a student-provided estimate. Table 3 shows the breakdown of their answers with 53 percent of the students reporting they spent 1-2 hour each week using the online textbook.

Response	Number of students (n = 40)
Do not use the online textbook	4
Less than 1 hour	12
1-2 hours	21
2 or more hours	3

Table 3: Weekly hours with online textbook

The students were also asked to score the online textbook components on a five-point scale with 5 being "very good" and 1 being "very poor." There was an option "have not used" so students who did not use that component would not judge it. The components were: readings, interactive activities, quick quizzes, and the interactive code writer. At the end of the course, the students were asked the same questions about the textbook. Thirty students answered the second survey.

	Midterm mean (n = 40)		Final mean (n = 30)		df = 68	
	M	*SD*	*M*	*SD*	*t*	*p*
Reading	3.75	1.4	3.73	1.3	.50	.652
Activity	3.43	1.6	3.40	1.7	.06	.407
Quizzes	2.90	1.9	2.97	2.2	-.1	.445
Code Writer	2.90	1.8	2.67	2.0	.52	.063

Table 4: T-test results comparing midterm and final evaluation of online textbook

After the midterm evaluation, the instructors realized that some students were not using the online textbook so the next lesson was taught in class with the online textbook. We wanted to know if the exposure in class changed their attitudes toward the book so students were asked questions about the online textbook at the end of the course. Independent samples t-tests were done to see if there were significant differences in the responses between the midterm and the final survey. Table 4 shows the results. There were no significant differences in how students rated the online text components between the midterm and final evaluations.

The component of the online textbook that was rated highest was the readings. Qualitative comments also reflected that the way the online textbook was written was well liked. There were several positive comments that the online text was "easy to read," "short, and "all information was there." Another popular theme regarding the online textbook was the interactive part. Students repeatedly mentioned that they liked the built-in quizzes and activities and liked to be able to work on their own and get feedback immediately.

Students also realized some challenges when working with the online textbook. The most common comment dealt with some kind of a technical issue where there were errors or a refresh was required to get the book to work. Some students mentioned they would like to have immediate feedback on the correct quiz questions. The feedback was available but students had to go to the online gradebooks to see which ones they missed. If they were just wanting to see the answers without taking the quiz first, then that option was not available. In addition, a few mentioned there were some navigation and search issues that made it hard to use. Others mentioned that the navigation and search capability was a positive.

The day that the instructors demonstrated the online textbook, the interactive code writer did not work as expected so the students were reminded they could always copy and paste the code into Thonny to test if the code writer did not work. In the final evaluation, the students were asked for their preference for using Thonny or the interactive code writer. Over 83 percent of the students said they would rather copy and paste code from the online textbook into Thonny instead of using the included interactive code writer. This is valuable feedback for future direction of the online textbook. Incorporating the interactive code writer was a challenging part of developing the textbook and required additional cost. Removing that component and having students copy and paste code into their preferred IDE may be a better fit for the book. We will need to explore this in order to keep the interactive component viable. Students were also asked about their preference for an online or paper textbook. The results were overwhelmingly in favor of having an online textbook instead of a paper textbook with 87 percent preferring online.

In addition to the data from the student surveys, the instructors were also able to obtain data regarding the use of the online textbook through the publisher's gradebook. The activities and quizzes from the online gradebook were not included as part of the course grade. However, instructors could see the online gradebook to tell which students had completed the activities and quizzes. For the activities, students received a 1 if they submitted the activity and a 0 if they did not. By submitting, they would learn if they got the answers correct. They received a 1 if they submitted, regardless of the accuracy of their work. There were a total of 47 activities in the online textbook. There were 15 quick quizzes in the online textbook. Students were timed on the quizzes but could take them multiple times, and the highest score was recorded in the online textbook gradebook. The quizzes were each worth 10 points. The total points available was 197 with 47 from activities and 150 from quizzes. Of the 36 students completing the course, 11 students (31 percent) showed no or very low interaction with the online textbook, earning fewer than 10 points in the online gradebook. Measuring the time spent reading or the amount of reading done in the textbook was not available through the online gradebook so could not be included in this analysis. All students who completed the course and received a grade were used in this analysis.

Final course grades are approximately 70 percent quizzes and exams, 15 percent programming projects, and 15 percent discussions and worksheets. To answer our third research question, we used regression to discover whether the grade from their online textbook gradebook was a valid predictor for their overall class percentage. Other predictors that were tested were the average quiz score, the total quiz score, the total number of activities completed, and the total number of activities and quizzes completed. A correlation matrix was generated and as expected, Pearson's coefficients ranged from .807 to .984, indicating a high level of correlation between the independent variables. Since multicollinearity existed as the predictors (independent variables) were related, each of these predictors was tested in simple regression (Hair, Black, Babin, Anderson, & Tatham, 2006). The best predictor for the overall course grade was the online textbook grade participation score. A significant regression equation was found ($F(1, 34) = 9.99$, $p < .003$), with an R^2 of .227. Participants' predicted course grade is equal to 77.34 (out of 100) plus .097 points for each point increase in online textbook participation. Table 5 shows the results of this analysis.

The average quiz score, total number of quizzes taken, total number of activities completed, and the total number of both activities and quizzes were all significant predictors as well but were not better than the online gradebook participation score.

	F (1,34)	R^2	*p*	b_0	b_1
Online text grade	9.9	.227	.003*	77.34	.097
Avg quiz score	8.9	.161	.015*	77.37	1.12
Total quiz taken	6.7	.164	.014*	78.66	.846
Total activ. comp.	9.3	.214	.004*	75.73	.309
Total quiz & activ. comp.	9.2	.214	.005*	76.17	.240

*Significant

Table 5: Simple regression results with course grade as dependent variable

5. DISCUSSION OF FINDINGS

The publisher's online gradebook score as a predictor shows that the effort that students put into the both activities and the quizzes when using the online textbook were relevant. This finding indicates completing activities as well as trying to do well on the quizzes (versus just attempting them) are better predictors of a student's final course grade over just viewing the activities. This finding reinforces that student interaction with online materials can lead to learning gain as also shown in Pollari-Malmi et al. (2017) and Farnqvist et al. (2016).

The researchers were encouraged with the positive feedback regarding the use of an online textbook. This finding contradicts what Robinson (2010) found in her study regarding preference as the majority of the students purchased a paper copy. This is likely due to increased acceptance in online materials in the last decade. Pollari-Malmi et al. (2017) also found increased usage in e-textbooks over pdf's. The textbook used in this study was offered free to all students, but only 69 percent used the book, reinforcing Robinson's (2010) finding that many students do not use a textbook even when provided free of charge.

Students scored reading the online textbook as the highest component. As previously mentioned, the online gradebook does not measure the amount of time that students spend reading so it's hard to know whether reading had a confounding effect on the results. Future studies will need to seek a better way to measure reading to determine its role in the final course grade.

Student comments regarding the ability to search, find, and navigate the online textbook were mixed. This could be due to some students using the book more to learn the features or there could be some usability issues that could be addressed. We will review the navigation and search and add some brief instruction in class so students will know how to use the online textbook. In addition, students may or may not have known how to find quiz feedback so that will also be part of our instructions in the future.

There are limitations to generalizing the results of this study. A larger sample size would make the results stronger. In addition, the dependent variable was course grade, and many factors influence final course grade other than the use of the online textbook. Continuing this study into future semesters will allow us to learn more about the impact of this online textbook.

6. CONCLUSION

The overall goal of this study was to examine the degree of utility and value of using an interactive online textbook in a computer programming course. Through analysis of surveys and data collected during a full term of using this resource in multiple sections of a beginning programming course, we have endeavored to answer three questions: what classroom activities were viewed as valuable by the student; how do students perceive the online textbook's usefulness in terms of its activities; is a student's online textbook grade a valid predictor for the overall course grade? Our findings were encouraging in that students were mostly positive in their feedback about the textbook, and that valuable information about the effectiveness of various classroom activities was collected. Additionally, we have data connecting the use of the online resource to a student's performance.

Educational techniques and student populations evolve constantly, which makes iterations of research in this area continually necessary. This particular topic is no different. As interactive online resources become more sophisticated and ubiquitous, no doubt there will be many opportunities for future research on this subject and improvement of these tools.

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Cloud Based Evidence Acquisitions in Digital Forensic Education

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Abstract

In a cloud computing environment, traditional digital forensic processes (such as turning off the computer to image the computer hard drive) can be disruptive to businesses because the data of businesses may be co-mingled with other content. As technology changes, the way digital forensics acquisitions are conducted are also changing. The change in methodology affects the way this subject matter is taught in programs and institutions. Methods to teach digital forensic acquisition methods in a cloud computing environment are limited due to the complexity of the cloud environment. This paper explores how a panel of expert practitioners viewed evidence acquisitions within the cloud environment, the implications for digital forensic education, and suggestions on how the education field can prepare students for technological changes in digital forensic acquisition processes where cloud computing environments are concerned and also help develop new methodologies. The paper offers a classroom case scenario as an example on how new methodologies and tools can be used in the classroom.

Keywords: digital forensics, cloud forensics, digital forensic acquisition methods

1. INTRODUCTION

The definition of digital forensic processes has been in existence for many years. Digital forensic processes consist of crime scene evidence collection, evidence preservation, evidence analysis, and presentation of the analysis results (Zimmerman, 2012). Traditional digital acquisition processes include maintaining chain of custody control of forensic evidence data. This chain of custody control occurs in the evidence collection phase through the imaging of a system (Decker, Kruse, Long, & Kelley, 2011). Cloud computing technology disrupts this initial step in conducting a digital forensic investigation and presents a problem for digital forensic investigators because it is not possible to take down and create a forensic image of such a large environment (James, Shosha, & Gladyshev, 2013).

As business models have changed to incorporate a wide variety of cloud computing environments, the escalation of computer crimes from hacking and security breaches related to cloud computing environments has steadily increased. Methods to investigate crime in a cloud computing environment are limited due to the complexity of the cloud environment. Cloud related criminal activity is likely to present security and forensic challenges for an extended period, spanning well into the future (Robinson, 2012). As institutions evaluate their curriculum in preparing students for entering the workforce, digital forensic teaching methodologies must encompass the acquisition of cloud computing related data.

2. BACKGROUND

The science behind digital forensics requires repeatable processes producing consistent results (Decker et al., 2011). Traditional forensic evidence acquisition processes do not fit well into cloud computing because of the way cloud computing works (Desai, Solanki, Gadhwal, Shah, & Patel, 2015).

Traditional forensics focuses on acquiring a complete image of the environment. Current digital acquisition processes include controlling forensic evidence data to maintain an unaltered state through the imaging of a system. With cloud computing environments, such an acquisition is not feasible.

Traditional digital forensic acquisition processes focus on individual computers and isolated environments, while cloud computing forensic acquisition processes include the intricacies of complex infrastructures including virtual servers, applications, and diverse operating platforms that may be located in foreign countries (James et al., 2013).

Cloud computing systems consist of multiple user environments, using a variety of services. Shutting down a cloud computing system disrupts services to all the user environments hosted on the system (Pătraşcu, & Patriciu, 2014). The common forensic procedure of shutting down the system in order to take a forensic image of the system cannot apply to hosted cloud services due to disruption of service to a wide scope of users.
Cloud computing systems using distributed file systems have large volume storage areas distributed physically across many geographic locations. The application of current forensic methods cannot be used because it is impossible to image and reconstruct separate replications of each disk node (Farina, Scanlon, Le-Khac, & Kechadi, 2015). The time, storage, and labor required to forensically collect and reassemble this environment is extremely extensive and quite unmanageable.

Many of the key aspects of proper evidence acquisition and handling such as evidence control, acquisition skills, and forensics tools need further development to meet the requirements to properly acquire digital evidence in cloud computing environments (Lallie & Pimlott, 2012). Prior research from a 14-member expert panel survey shows that eleven (79%) of the panel members felt the knowledge and skill requirements for cloud environments were different for cloud computing forensics acquisitions and non-cloud computing forensic acquisitions.

Predefining skill requirements where cloud computing environments are concerned is impossible due to the dynamically changing environment (Goodall, Lutters, & Komlodi (2009). The nature of such expertise makes transferring those skills to other examiners problematic (Goodall et al., 2009). New analysts cannot properly validate the information in the reports without extensive knowledge. Network security tool creators and vendors must recognize the vital role human expertise plays in report validation.

3. PRACTIONER VIEWS

In order to garner opinions on cloud forensics and the application of traditional forensic acquisition methods to cloud forensic environments, an expert panel survey was conducted. In this study, a qualitative research methodology based on the Delphi technique was used to collect data from a sample of digital forensic subject matter experts. Expert panel member selection was based on the criteria from a submitted statement of qualifications. Only digital forensic investigators with at least five years of relevant field experience, published work, industry presentations, and recognition were eligible to participate in this study. The expert panel consisted of 14 members from several countries.
Fourteen panel members were selected because an ideal Delphi panel consists of 10-18 members. The 14 panel members were selected based on the extent of their knowledge and experience.

An online written narrative interview questionnaire for the study began with 10 open-ended written questions on cloud computing based on the cloud study by Ruan Baggili, Carthy, & Kechadi (2011) as defined in Appendix A. Panel members were then asked to evaluate 20 common forensic procedures for applicability to cloud computing environments. The common forensic procedures selected are listed in Appendix B.

The findings demonstrated there were very diverse opinions on cloud computing, cloud forensics, and the effect cloud computing environments had on digital forensics. Standard evidence acquisition procedures, federal and local laws, court accepted methods, and the cooperation of the cloud provider were all factors that affected the way a successful forensic acquisition was conducted in a cloud computing environment. The areas of tools, processes, and guidance available for forensic evidence acquisitions in cloud computing were relatively immature.

A recap of the responses to the evaluation of the 20 common forensic procedures for applicability to cloud computing environments indicated several key points. Only eleven (55%) of the 20 pre-selected traditional forensic processes were usable for the forensic acquisition of digital evidence in cloud computing environments and the usability of those processes had some limitations. Post-acquisition processes were most suited for application in cloud computing environments. Seven (35%) the 20 pre-selected traditional forensic processes were modifiable for the forensic acquisition of digital evidence in cloud computing environments depending on the level of access and service provider cooperation. Pre-acquisition processes were most suited for modification in cloud computing environments. One (5%) of the 20 pre-selected traditional forensic processes required the development of new processes for the forensic acquisition of digital evidence in cloud computing environments. Table 1 depicts these findings. The panel members suggested that pursuing the development of new processes in some cases was moot because the processes were irrelevant to cloud computing environments.

4. IMPLICATIONS FOR DIGITAL FORENSIC EDUCATION

According to NIST (2014), cloud computing is projected to drastically alter first responder and examiner processes. Practitioners agree that the knowledge and skill requirements for cloud are different for cloud computing acquisitions and non-cloud computing forensic acquisitions. In order to prepare digital forensic professionals for this change in processes, practitioner education will be needed (Holt & Bossler, 2011). This will require additional funding for new program development that will accommodate the projected alteration of first responder and examiner processes. Education on acquisition procedures will be in need the most.

Cloud forensics is a relatively new area of digital forensic practices with few industry professionals capable of providing required training (Ruan et al., 2011). The organizations and universities that build and deliver curriculum in digital forensic areas that involve cloud computing acquisitions need to participate in the advancement of the digital forensics field. Academia and the digital forensic training community will need to create and encourage the development of new training programs so that practitioners may better respond to situations where the acquisition of cloud computing environments are required. The expert panel study results provide compelling reasons for individuals currently involved in cloud forensics research to provide direction and advice for those implementing training programs, courses, or curriculum including education for law enforcement and industry professionals for the advancement of the profession in the ability to pursue cybercriminals.
Academia and the digital forensic training community need to create and encourage the development of new training programs so that practitioners may better respond to situations where the acquisition of cloud computing environments are required. The development of training programs, courses, or curriculum is dependent on existing knowledge. The panel research produced a contingency framework connecting the study results to practice as shown in Figure 1, Appendix C. This represents an illustration of the digital evidence forensic acquisition cloud contingency model.

As an example of how the model can be applied, the pre-acquisition process of performing procedures identified in a forensic acquisition checklist is used in Figure 2. The purpose of this example is to illustrate the application of the theory behind the model as an approach to guiding the relevance of the model to real-life situations. The process is the starting point because it is the constant. Three primary types of cloud environments of private, public and hybrid are used to introduce uncertainty. Based on the themes extracted from the study results, contingencies for determining if performing procedures identified in a forensic acquisition checklist include fluidity of environment, legal accessibility, and identification of the acquisition target. The contingencies then determine whether the process can be applied, requires modification, or if a new process is required to be developed and is illustrated in Figure 2 of Appendix C.

The premise of the digital forensic acquisition cloud contingency model is that in order to be effective, the process application methodology must be flexible and adapt to the contingencies produced by the cloud computing environmental situation. The resulting contingency model is well suited to a wide range of cloud computing environmental applications.

The general framework presented is populated with specific digital forensic acquisition process categories, a recommendation as to the applicability, and the contingency variables upon which the process application is dependent. This format makes it an ideal starting point for training or education in this area. The applicable forensics processes that ported over well to cloud computing environments occurred because similar processes are used in current live analysis and network forensics methods. This provides a basis for expanding network forensics to either include cloud forensics as part of this domain or develop new training and education based on the domain. The base of forensic knowledge is expanded by researching information and incorporating the ideas of others into training and education programs.

5. AVAILABLE TOOLS

Representatives of the Cloud Security Alliance and forensics practitioners agree that there is a need for additional research to create a framework of methodologies and establish processes that will hold up when challenged in a court of law (Zimmerman & Glavach, 2011). There is a need to develop a forensic architecture for cloud computing environments. Many of the key aspects of proper evidence acquisition, handling, and analysis such as evidence control, acquisition skills, and forensics tools need further development to meet the requirements to properly acquire digital evidence in cloud computing environments (Lallie & Pimlott, 2012).

Digital forensic investigators must broaden digital forensic practice tools and expertise to include cloud computing environments. The current mature tools, processes, and expertise for digital investigations focus on small, individual environments (Svetcov, 2011). There is still an emphasis on imaging all devices in the environment and a belief that if there are any changes to the media where the data is stored during the acquisition process, the data is not reliable where the courts are concerned (Cohen, 2011).

Cloud computing environments make it extremely impractical to conduct in-depth analysis on each bit of storage media (James et al., 2013). Forensic labs do not have the capacity required to process large quantities of media in a timely manner. Forensic tools become unstable when case files become too large and weeks or months of work is negated if the created case file consistently becomes unresponsive because the data capacity is too large for the tool to handle (Svetcov, 2011).

Cloud computing forensic evidence acquisitions pose challenges at a more rudimentary level, the acquisition itself. In a cloud environment, the examiner has few options to image the virtual machine remotely, and deploying a remote forensic agent requires administrative credentials. In some instances, there may be a willingness to conduct an internal acquisition by the provider (Dykstra & Sherman, 2011). However, in many cases the information is proprietary and confidential so the provider is reluctant to turn over any raw data.
Tools will gradually become outdated and computer forensic practitioners will no longer be able to rely on forensic analysis results, unless the forensic community formulates a vibrant strategy for developing methods that build upon each other. Garfinkel (2010) argued that the digital forensic investigative practice has been in a golden age and that golden age is rapidly ending and proposed a plan for realizing research and operational effectiveness by using forensic computation systematic approaches. Garfinkel (2012) further stated that writing digital forensic tools is difficult because of the diversity of data types that needs to be processed, the need for high performance, the skill set of most users, and the requirement that the software run without crashing.

Vital aspects of proper evidence acquisition necessitate additional development of forensics tools to meet the requirements for properly acquiring cloud computing environments (Zhou, Cao, & Mai, Y, 2012). An unexpected finding was that even a panel of experts experienced difficulty agreeing on some processes when discussing the application of digital forensic evidence acquisition methods to cloud computing environments. Four (29%) panel members felt there were no current tools available with which to conduct forensic acquisitions in cloud computing environments and five (36%) felt the current tools for non-cloud environments were sufficient to conduct forensic acquisitions in cloud computing environments. Four (29%) panel members identified a specific forensic tool, F-Response, as the only available tool capable of performing forensic acquisitions in cloud computing environments. One (7%) panel member indicated that current eDiscovery tools had the capability to accomplish forensic acquisition tasks in cloud computing environments.

The development of training programs, courses, or curriculum is dependent on existing knowledge. There are compelling reasons for individuals currently involved in cloud forensics research to provide direction and advice for those implementing training programs, courses, or curriculum including education for law enforcement and industry professionals for the advancement of the profession in the ability to pursue cybercriminals.

6. EDUCATIONAL IMPLEMENTATION EXAMPLE USING A CASE SCENARIO

Cloud environments are difficult to access in a forensic manner because the environment is live and the evidence cannot be logged into directly as it violates preserving the state of data and alters the data state. This can be compared to looking through a hard drive to find evidence without first creating a forensic image of the drive. The first rule of evidence is to never work on original evidence. The scenario acquisition process combined with the VM tools produces the repeatable processes necessary for the preservation of evidence and validation required. Based on the expert panel research and the contingency model created, a class project was created.

The basis of the project was an e-Discovery factual case scenario. The case scenario is based on several work-related legal issues but is a good starting point because it encompasses many different types of cloud based evidence. The case involves an employee of a worldwide organization that became disgruntled when he was accidentally copied on an email about a promotion he was being denied. In turn, the disgruntled employee exfiltrated company data to take with him after accepting a position with a competitor. During this time, the employee began communication with an old high school girlfriend who had located him on Facebook and he confided pertinent information with her. The scenario was used to build a cloud computing scenario by creating cloud based artifacts.

The scenario includes many cloud components including cloud based email, cloud based personal storage, social media, and cloud based corporate storage. The evidence items encompass personal e-mail accounts, Facebook pages, corporate storage buckets on Amazon Web Services (AWS), and personal storage on DropBox, Box, and Google Drive. The project is broken into two parts: an initial fact finding and exploration part and an actual acquisition part. Breaking the project into two parts gives the students practice in using cloud environment acquisition tools and allows students to become familiar with the process of doing an acquisition in a cloud computing environment. Privacy and legal considerations are discussed in the scenario since some of the storage buckets are located in foreign countries.

The investigative environment consists of a virtual machine (VM) that contains several forensic tools such as Access Data’s FTK imager, F-Response Universal, and Paraben’s E3 DS. Paraben E3 and F-Response access the cloud environment through an authentication API. Basically the tools act as an intermediary between the forensic examiner and the cloud environment. This allows evidence to be mounted as read-only and prevents direct access by the examiner. Then standard validation processes such as hashing can be conducted. This is an acceptable process from a forensic standpoint. In the classroom, the process does not allow the student to touch the original evidence, reinforcing proper forensic procedures.

Once the environment is accessed, both F-Response Universal, and Paraben’s E3 DS can compress, hash, and export the data. The evidence is preserved in a forensic manner using this process. Once the acquisition is complete, the evidence is analyzed in the same manner as any other evidence. This validates the expert panel findings that post-acquisition processes were most suited for application in cloud computing environments.

Cloud acquired evidence is analyzed in the same manner as any other acquisition. This process is supported by prior research from the 14-member expert panel survey. Post-acquisition processes were most suited for application in cloud computing environments. Following post-acquisition processes in order of applicability were live acquisition processes.

There are a few important points worth mentioning. Credentials are needed in order to access the environment. The authentication of the accounts requires logins and passwords. Authentication keys are required to access AWS storage. As long as all parties are cooperative this information will be available. If the parties are not cooperative, the process cannot be used. When parties are not cooperative, any investigation is impeded, whether it is a cloud-based or a traditional forensic based investigation. When two-factor authentication is used, the process will be difficult as currently tools are not set-up to access information when two-factor authentication is required. This difficulty is encountered whether it is a cloud-based or a traditional forensic based investigation. Privacy and legal issues are a consideration, especially since the passage of General Data Protection Regulation (GDPR).

The case results indicate the learning methodology used was successful. Some students took the path of least resistance and logged into several of the accounts instead of thinking outside the box. This breach of forensic process resulted in lower scores for those students. Assessment results from the Fall 2019 section of the class show that overall scores improved between the initial assessment in Week 4 and the final assessment in Week 8. The average score in Week 4 was 60%, with a median grade of 72%. In week 8, the average score was 69%, with a median grade of 79%.

7. FUTURE RESEARCH AND WORK

The opportunity for researchers to make innovative contributions and substantial impact to the cloud computing industry has only just begun (Zhang, Cheng, & Boutaba, 2010). The findings from the expert panel study are a bridge to a very small body of literature. The results of the study produced a contingency framework and digital evidence forensic acquisition cloud contingency model to help guide a course of implementation that can test the model and be used in teaching methodologies.

Using contingency frameworks to address other research questions provides a different perspective on the application of digital forensic acquisition methods to cloud computing environments. Additional studies could firmly establish that the choices available for the application of digital forensic methods to cloud computing environments are ingrained in contingency frameworks. One of the significant contributions of the expert panel study is the identification of contingency factors such as available tools, access, availability, and acquisition scope as the underlying elements when choosing the application of digital forensic methods to cloud computing environments. These contingency factors are easily ported to other evidence acquisition methods for expanding teaching and research in this area.

The digital evidence forensic acquisition cloud contingency model suggests other important directions of research and teaching methodologies. Accepting a contingency perspective on how to choose digital process application in cloud computing environments can serve as a powerful theoretical lens both in interpreting the results of prior models and in shaping rigorous research models for future inquiry. Another direction for future research and teaching would be to examine the influence of multiple contingencies on the process application within individual cloud types.

The expert panel study was conducted using a 14 member expert panel, which is a very small subset of all practitioners and researchers in the digital forensics field. A similar study can be performed using a larger sample. Carlton (2007) identified 103 forensic acquisition tasks. The task identification encompassed three phases of a digital forensic acquisition based on tasks performed during investigation preparation, the actual event, and concluding tasks. This same study can be conducted on an expanded set of processes to include more than the 20 identified processes used in the study. Future study options would be to include all 103 identified processes, restrict the study to one of the phases outlined by Carlton (2007), or re-evaluate the processes identified by Carlton to identify which of the 103 processes are still relevant.

8. CONCLUSION

Educating students in a constantly changing technological environment presents challenges to the academic field. The purpose of this paper was to explore how a panel of expert practitioners viewed evidence acquisitions within the cloud environment, the implications for digital forensic education, and suggestions on how the education field can prepare students for technological changes in digital forensic acquisition processes where cloud computing environments are concerned. A case scenario project was included to show how new processes can be incorporated into the classroom.

The work contained within is based on a qualitative Delphi study used to develop a robust contingency framework through the evaluation of 20 conventionally recognized forensic acquisition processes by a panel of subject matter experts (SMEs). The knowledge and skill requirements for conducting acquisitions in a cloud computing environment differed from a non-cloud computing environment but there was very little guidance available for digital forensic professionals on conducting acquisitions in a cloud computing environment. As an industry, digital forensics is lacking the tools, published processes, and guidance for proper acquisition of digital evidence in cloud computing environments. Pre-acquisition processes are most suited for modification in cloud computing environments while post-acquisition processes are most suited for application in cloud computing environments. The digital acquisition processes that applied to cloud computing environments were modeled after already established network forensic processes.

A sample case example was included to demonstrate validation of the expert panel findings and show how the study results can be incorporated into the classroom environment. The scenario includes many cloud based forensic evidence items. The scenario addressed the privacy and legal considerations associated with cloud-based evidence. The process used in the case example project provided students with hands-on experience using tools for cloud-based evidence acquisitions that are different from traditional digital forensic tools.

Recommendations for educators included improved training and education. Recommendations for future research included expanded contingency theory application, targeting specific types of cloud computing, using a larger sample population, and expanding the number of acquisition processes examined. Once the research is completed porting over these processes to the educational environment is the next step to producing new teaching methodologies and forensic processes. Creating new scenarios such as the one provide in this paper furthers the development of training programs, courses, and curriculum for the existing body of knowledge.

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Appendix A: Online Written Narrative Interview Questions

Please answer the following open ended questions based on your expert opinion:

1. What is cloud computing?
2. What is cloud forensics?
3. What impact does cloud computing have on digital forensic acquisitions?
4. What challenges does the area of cloud forensics currently face?
5. In what ways are cloud forensic acquisitions more or less complex when compared to similar non-cloud forensic acquisitions?
6. Who is responsible for the acquisition of cloud computing forensic evidence in civil and in criminal cases?
7. How are the knowledge and skill requirements different for cloud computing acquisitions from non-cloud computing forensic acquisitions?
8. What current tools are available with which to conduct forensic acquisitions in cloud computing environments?
9. What published processes are available that describe forensics acquisitions in cloud computing environments?
10. What current guidance is offered on the forensic acquisition of evidence in cloud computing environments?

Appendix B: Online Written Narrative Questions Regarding the 20 Selected Forensic Processes

Please answer the following open ended questions based on your expert opinion as to the applicability of the following tasks to cloud computing environments. Explain how the following traditional processes can be applied to cloud computing environments. If the process cannot be applied and the process can be modified or a new process has to be developed, please provide your opinion on what the modified or newly developed process would look like.

1. Perform procedures identified in a forensic acquisition checklist
2. Perform a RAM dump
3. Collect volatile data
4. Perform a live image acquisition of the computer
5. Photograph the displayed image shown on the computer's monitor
6. Determine the programs currently running on the computer
7. Power off the unit by using the operating system shutdown method
8. Determine the current date and time from a reliable source
9. Document the manufacturer, model, and serial number of all storage media attached to the computer
10. Remove the hard disk drive(s) from the system unit
11. Document number of hard drives, size and disk geometry
12. Use EnCase to obtain an image of suspect media
13. Use AccessData's FTK to obtain an image of suspect media
14. Use UNIX/Linux dd command to obtain an image of suspect media.
15. Identify any network connections, and document findings
16. Generate a MD5/SHA1 hash value of the forensic image
17. Preserve suspect media in its original condition and securely seal
18. Place suspect media in a secure storage area or evidence vault
19. Create a clone copy of suspect media for mounting and analysis
20. Perform a visual comparison of the directory structure of the image and the suspect disk to verify that the image is readable

Appendix C: Figures

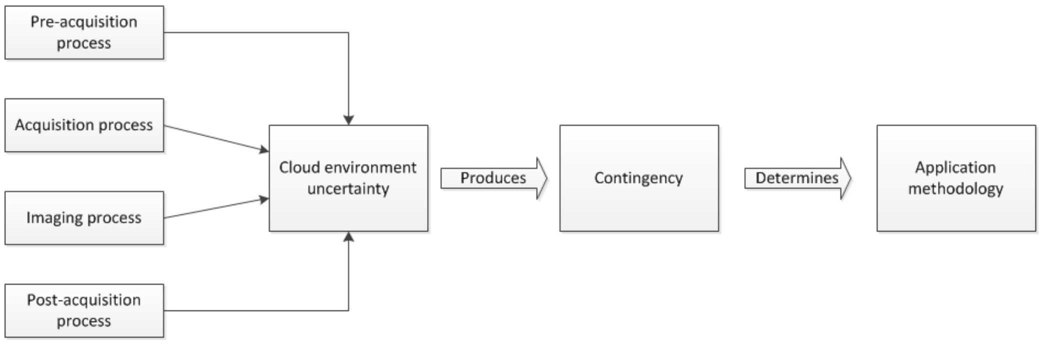

Figure 1. An illustration of the digital evidence forensic acquisition cloud contingency model

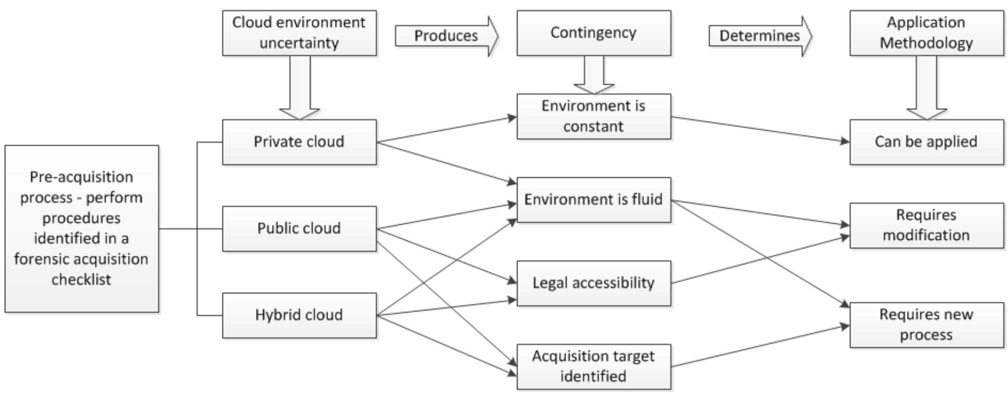

Figure 2. Application of the digital evidence forensic acquisition cloud contingency model to pre-acquisition process.

Appendix D: Tables

Table 1

Study Results of the 20 common forensic procedures for applicability to cloud computing environments

Forensic Procedure identification	Number of procedures
Traditional forensic processes usable for the forensic acquisition of digital evidence in cloud computing environment	11
Traditional forensic processes modifiable for the forensic acquisition of digital evidence in cloud computing environments	7
Traditional forensic processes required the development of new processes for the forensic acquisition	2

Teaching Applications and Implications of Blockchain via Project-Based Learning: A Case Study

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Abstract

This paper presents student projects analyzing or using blockchain technologies, created by students enrolled in courses dedicated to teaching blockchain, at two different universities during the 2018-2019 academic year. Students explored perceptions related to storing private healthcare information on a blockchain, managing the security of Internet of Things devices, maintaining public governmental records, and creating smart contracts. The course designs, which were centered around project-based learning, include self-regulated learning and peer feedback as ways to improve student learning. Students either wrote a research paper or worked in teams on a programming project to build and deploy a blockchain-based application using Solidity, a programming language for writing smart contracts on various blockchain platforms. For select student papers, this case study describes research methods and outcomes and how students worked together or made use of peer feedback to improve upon drafts of research questions and abstracts. For a development project in Solidity, this study presents the issues at hand along with interview results that guided the implementation. Teams shared lessons learned with other teams through a weekly status report to the whole class. While available support for the Solidity teams was not ideal, students learned to use available online resources for creating and testing smart contracts. Our findings suggest that a project-based learning approach is an effective way for students to expand and develop their knowledge of emerging technologies, like blockchain, and apply it in a variety of industries.

Keywords: blockchain, distributed ledger, emerging technologies, project-based learning, self-regulated learning, peer learning

1. INTRODUCTION

Project-based learning (PjBL) is a pedagogical approach in which students take primary responsibility for their learning through focused inquiry (Barron et al., 1998; Gordon & Brayshaw, 2008; Thomas, 2000). One area where this approach has been successful is learning and applying an emerging technology in the context of a project that students define and develop (Bell, 2010; Gibson, O'Reilly & Hughes, 2002; Yue, Chandrasekar & Gullapall, 2019).

Blockchain is an important and timely example of an emerging technology. It also has the potential to be disruptive in many different industries (Bambara & Allen et al., 2018). Such potentially disruptive technologies are of are interest to students since they present opportunities to consider and study applications that are new, different, and exciting. Blockchain's first use cases were to mediate payments, which led to blockchain's early adoption in financial services (Hileman & Rauchs, 2017). More recently blockchain has been proposed for a much more diverse range of applications (Bashir, 2018).

As summarized in Figure 1, a well-designed project-based learning experience is one in which the student has ownership of the project. Furthermore, student learning outcomes are improved if the project demands both creativity and critical thinking (Rice & Shannon, 2016; Weimer, 2013). Finally, in many learner-centered environments, different forms of collaboration, e.g., peer learning and peer teaching, often improve the quality of course projects (Aditomo & Goodyear et al., 2013; Jackson & Bruegmann, 2009; Stefanou & Stolk et al., 2013).

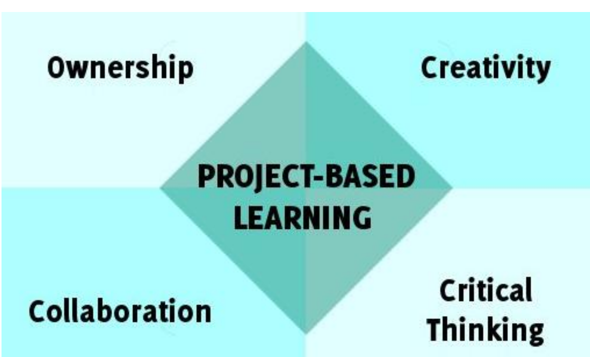

Figure 1. Key aspects of project-based learning [Adapted from (Stefanou & Stolk et al., 2013)]

A central goal of this study is to understand how students learned and applied the fundamentals of blockchain technology via PjBL. The remainder of this paper is organized as follows: Section 2 provides a brief overview of blockchain technology. Section 3 describes how the learning goals of blockchain courses at Bryant University and Bentley University were supported by PjBL. Section 4 presents and analyzes four student projects, and finally we conclude with some reflections and lessons learned after delivering these courses.

2. BLOCKCHAIN OVERVIEW

A blockchain is a continuously growing ledger of transactions that are grouped into blocks. Each block is linked to the prior block and secured using cryptography. By design, a blockchain is immutable, meaning that it is highly resistant to modification of the data that has been recorded on the chain. The ledger is distributed amongst all nodes in the network. Each node has a copy of the entire transaction history. When a new transaction is generated, all nodes in the network verify the transaction; this is known as consensus.

A blockchain can be either permissioned or permissionless. Permissionless blockchains, like Bitcoin and Ethereum, mean that anyone can participate by generating transactions while in a permissioned chain only those with permissions can generate transactions. In addition, blockchains can be either public or private. This indicates who can see the transaction history. Anyone can see the history in a public blockchain while only certain entities can see the transactions in a private blockchain (Norman, 2017).

The initial concept behind blockchain technology was produced in a white paper by the anonymous author Satoshi Nakamoto (2008) and was used as the foundation on which the Bitcoin cryptocurrency was launched. Since its launch, Bitcoin has grown to a market cap of $151B (as of October 1, 2019).

However, the Bitcoin blockchain is limited in functionality to a single application, that being the cryptocurrency Bitcoin. Others recognized that the underlying blockchain technology could have much wider application with some key changes. In 2014 Anatoli Buterin published a whitepaper that introduced the concept of *smart contracts*, or code that could be embedded and executed on the blockchain (Buterin, 2014). This became the foundation for the Ethereum blockchain. While the Ethereum blockchain has a cryptocurrency like Bitcoin, it also supports a myriad of other applications.

While both Bitcoin and Ethereum are public blockchains, meaning that anyone can see any and all transactions that occur on the blockchain, businesses often need additional flexibility to manage who can participate in and view transactions. As a result, in late 2015 the Linux Foundation launched Hyperledger which has emerged as a leading blockchain for developing enterprise applications (Sharma, 2019) and is often used by businesses in areas, such as supply chain, where transactions may be visible based on permissions (Wüst & Gervais, 2018).

Looking at a recent Gartner Emerging Technologies Hype Cycle (Gartner, 2018) shown in Appendix A, Figure 5, one can see that blockchain is moving away from the peak of inflated expectations and towards the trough of disillusionment. As a result, one could surmise that the interest in blockchain will wain overall. However, as Pisa (2018) argues, the early excitement of blockchain was based on the public, permissionless blockchains like Bitcoin and Ethereum and a second wave of interest may be emerging around permissioned ledgers such as Hyperledger.

While blockchain emerged as a platform by which a cryptocurrency could be maintained, its applications are far-reaching and well beyond financial uses. Blockchain has application in areas such as digital supply chains (Korpela, Hallikas, & Dahlberg, 2017; Tian, 2016), digital government, including land records and voting (Jun, 2018; Ølnes, Ubacht, & Janssen, 2017), and gaming (Gainsbury & Blaszczynski, 2017; Piasecki, 2016), just to name a few.

3. PROJECT-BASED LEARNING AND LEARNING GOALS

According to Blumenfeld et al. (1991), the essence of project-based learning is that a question or problem serves to organize and drive student activities. Although the central features and benefits of PjBL are well understood (e.g., see Figure 1), specific implementations of this instructional approach vary widely (Aditomo & Goodyear et al., 2013; Zimmerman, 1990). For example, Thomas (2000) and Helle et al. (2006) agree that projects should have students "encounter (and struggle with) the central concepts and principles of a discipline" (Thomas, 2000, p. 3). Furthermore, in a post-secondary setting, projects should engage students in a significant constructivist activity resulting in a thesis, report, model, design plan, computer program, composition, or performance (Helle, Tynjälä & Olkinuora, 2006). Because of the focus on business education at both universities involved in this study, Bryant and Bentley feature PjBL as central to our curricula, as it would be in other disciplines, e.g., engineering (Hadim & Esche, 2002). This means that the students in our classes, who were mostly juniors and seniors, had experience working on both team and individual projects before taking our courses.

Many of the outcomes due to PjBL in the context of the courses offered at Bryant and Bentley were consistent. The most successful projects were the ones in which students took the greatest initiative (Weimer, 2013), were most resourceful (Bell, 2010), and worked the hardest (Freire, 1993).

In spite of the common connection to blockchain technology, however, some differences in the educational activities enabled and even catalyzed student projects. The *Introduction to Blockchain* course at Bryant (see Appendix B) was designed for more technically-oriented students with some programming background. Hence students were required to learn Solidity, a programming language for writing smart contracts, and implement a simple smart contract in an Ethereum development environment during the first half of the course. This exercise supported two of the five learning goals of the Bryant course: to enable students to evaluate and develop smart contracts using the Solidity language, and to enable students to recognize the unique challenges of implementing blockchain including the inability to easily change smart contracts and the inability to reverse transactions. (See Appendix B.)

In contrast, the *Blockchain: Applications, Policy and Implications* course at Bentley (see Appendix C) was designed for more managerially-oriented honors students from diverse academic backgrounds. Specifically, the seven students in this class hailed from five different majors. Their initial activities required that they complete selected readings – taken from (Bashir, 2018; De Filippi & Wright, 2018; Hevner & Chatterjee, 2010; Norman, 2017) – and engage in discussions and design exercises in class. Taken together these activities supported the second and third learning goals for this course. (See Appendix C.) Unfortunately, because these honors students were engaging in these instructional activities while also refreshing their skills related to research methods (Saunders, Lewis & Thornhill, 2016), the students often felt overwhelmed by their capstone experience.

Even though the student audiences at Bentley and Bryant were different, the connections between the foundational educational activities and learning goals for each course were similar. For example, in the Bentley course, the critical literature review due in week six helped assure that each student was on a trajectory to conduct original research by having them situate their research project within the current literature. This activity directly supported the fourth and fifth learning goals for the Bentley course. For students on the research track in the Bryant course, the industry-focused midterm paper due in week seven helped assure the rigor and relevance of the final projects and also supported the fifth learning goal for the Bryant course.

As a final note, although self-regulated learning is common in project-focused courses (Saks & Leijen, 2014; Stefanou & Stolk et al., 2013), it played out very differently in our two courses. Discussion of this finding is deferred to Appendix B and Appendix C, after a discussion of student projects in the next section and lessons learned in Section 5.

4. BLOCKCHAIN STUDENT PROJECTS

To successfully complete their coursework students either wrote a research paper, in phases, during the semester or worked in teams on a Solidity programming project. To provide an interesting cross-section of the student projects, we describe four of the sixteen projects in the next four subsections.

Bryant Student Project by Cayla D'Amico: Healthcare Privacy

The first student project explores the security concerns related to storing private individual healthcare-related information on the blockchain. This work explores one of the key factors driving blockchain adoption in healthcare, the privacy and security of private health information as well as key factors inhibiting growth, the challenge of an immature infrastructure, and the risks associated with patient-controlled health data (Rabah, 2017). While others (Peterson, Deeduvanu, Kanjamala, & Boles, 2016) have focused on creating blockchain-based solutions for the healthcare industry, they fail to distinguish between the varying types of health data and whether some data is more appropriate for the blockchain than other data. This work intended to extract patient concerns related to different types of health information, which could lead to suggestions on which data might be better received given the challenges of this immature technology.

D'Amico used a survey to elicit responses from 100 individuals ranging in age from 19 to 73. She used her personal network, which included several relatives who work in healthcare, to distribute the survey.

Recognizing that the general public lacks knowledge about blockchain, the survey instead focused on the underlying features that could be enabled using blockchain technology. She found that 75% of the respondents felt confident that their personal data was kept safe and secure. Younger respondents were more likely to trust that their data was secure over older respondents, as shown in Figure 2.

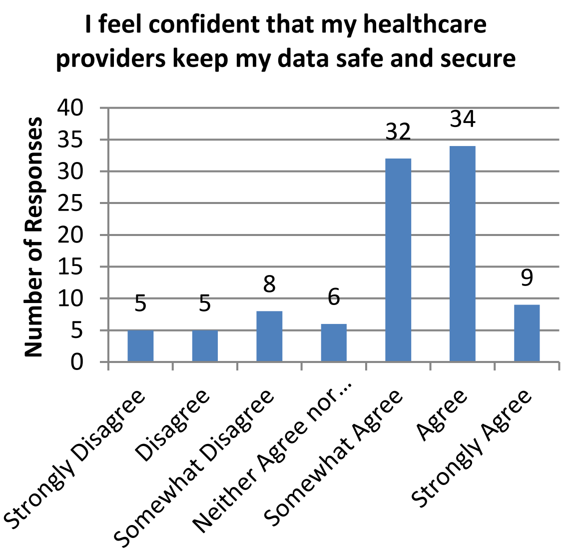

Figure 2. Confidence in security of healthcare data

When asked about specific security concerns (HIPPA, hackers, and poor system controls), the majority were concerned most with hackers, followed by the leaking of the data as a result of poor controls, and finally HIPPA violations, as shown in Figure 3.

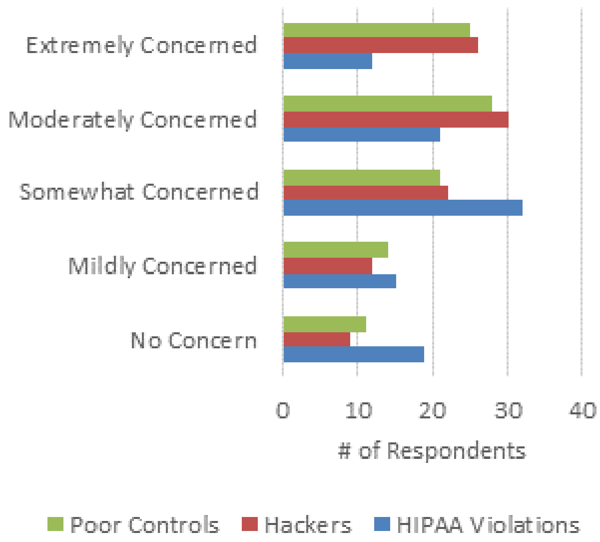

Figure 3. Security concerns related to healthcare data

She then tried to uncover what types of information are less sensitive than others. Her rationale was that pilot studies could potentially focus on data that is of less concern until public confidence in the new technology has been obtained. This was measured by how much money a person would have to be paid to share this information. As shown in Appendix F, Figure 8, respondents were more likely to sell data such as eye and dental history, while respondents were either unwilling to sell, or only would sell for higher amounts, data such as DNA and disease history.

Discussion

Through the weekly status reports, D'Amico was able to discuss and pilot her survey instrument which went through several iterations. Feedback from others helped her add questions that would allow for the accounting of whether someone felt they had personally embarrassing information or not. She was able to explain the constructs she was trying to measure and get feedback on better ways to word questions or ways to ask additional questions to get better responses.

D'Amico's challenge was how to measure the appetite for an emerging technology, knowing that those she would be asking about that technology would have little to no understanding of the technology. In order to do this, D'Amico had to understand the risks and opportunities of the new technology so that she could ask questions related to those risks and opportunities.

Bentley Student Project by Yishan Wang: IoT Security

The second student project explores the benefits of using blockchain to improve the security of Internet of Things (IoT) devices (Sicari, Rizzardi, Grieco, & Coen-Porisini, 2015). Wang used a design science research approach to this problem (Hevner, 2007; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007; Vaishnavi, Kuechler, & Petter, 2019) targeting a *knowledge contribution* that represented a substantive improvement over existing designs (Gregor & Hevner, 2013). Figure 4 summarizes how Wang's project achieved this goal: IoT security was considered part of an application domain – information security – that is quite mature, since early work in the area dates back to the 1970's (Saltzer & Schroeder, 1975). This placed Wang's study in the *improvement* or *routine design* quadrants in Figure 4. This study was a knowledge contribution that was an *improvement* over prior research since it addressed novel and significant research objectives, which in aggregate represented a research opportunity, placing it in the top left quadrant of this figure.

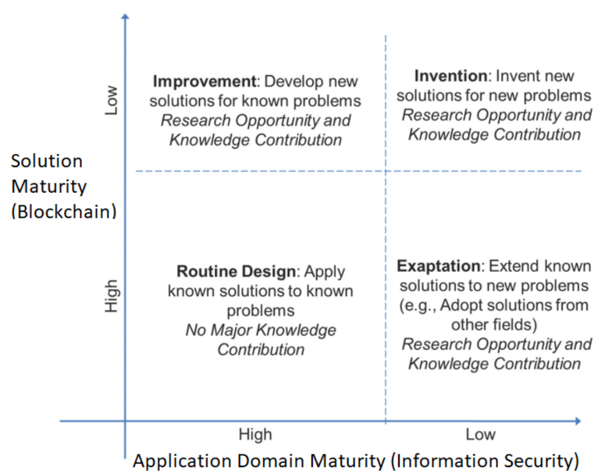

Figure 4. Knowledge contributions of Gregor & Hevner (2013) showing the research potential of blockchain-based solutions to address information security problems

This project had four research objectives:

1. To understand ways that blockchain could improve the confidentiality, integrity, and availability of the data processed and stored in IoT devices.
2. To understand how blockchain can reduce or eliminate single points of failure in IoT device deployments.
3. To assess the role of edge or fog computing and how they can help secure IoT devices.

4. To explore and assess the feasibility of design proposals through analyzing specific applications and use cases.

Perhaps the most important insight of this project was that since almost all design is domain dependent (Suh, 1998), there is no one size fits all solution that solves the "IoT security problem." For example, the security policies and mechanisms used to secure the IoT network in a hospital likely would be different from those used to secure IoT devices in a smart home. Because of this insight, Wang proposed a framework for securing IoT devices with respect to their computation, communication, and storage (McCumber, 1991) by pairing each IoT device (or a set of devices) with a block on a permissioned blockchain. Thus, by leveraging edge computing principles, each "IoT security block" acts as a gateway for three secured services:

A. Access control for invoking underlying services provided by the IoT devices;
B. Information flow management for consuming data elements or data streams produced by the IoT devices; and
C. Monitoring and alert information services about the overall health of the IoT devices, including their security health.

By requiring (and enforcing) that applications only configure, access, and use IoT devices via their associated IoT security block, the IoT devices inherit the security properties of their security block. If the IoT devices can serve as both data sources and data sinks, information flow must be managed and secured in both directions.

Designing for security is never perfect, however, the blockchain-based IoT security framework proposed in this second project, with the appropriate assurance (Bishop, 2018), would provide robust protection for four out of the Top 10 IoT security vulnerabilities (Paul, 2019):

- Insecure network services;
- Insecure ecosystem interfaces;
- Insufficient privacy protection; and
- Insecure data transfer and storage.

Furthermore, services A, B, and C above could provide some protection against some vulnerabilities in the IoT devices:

- Insecure default settings (e.g., by overriding unsafe default configurations and settings);
- Weak, guessable, or hardcoded passwords (e.g., by blocking access to or securing these insecure interfaces); and
- Lack of device management (e.g., by implementing minimal control and status functions in the security block).

The most interesting use case analysis in this project demonstrated that securing the seven above vulnerabilities would have been sufficient to stop the Mirai botnet attack on the Domain Name System in October 2016 (Kolias, Kambourakis, Stavrou, & Voas, 2017; Tan, 2018).

Unfortunately, within Wang's framework, there are three vulnerabilities that cannot be protected by a permissioned blockchain designed to secure IoT devices:

- Lack of secure update mechanism;
- Use of insecure or outdated components; and
- Lack of physical hardening.

This is because such vulnerabilities typically are present in (or absent from) the design or deployment of the IoT devices themselves.

Peer Assessment and Discussion

Wang's peer, LGZ, provided important comments about Wang's project. LGZ highlighted that Wang's original research question was too vague, and LGZ guided him to narrow it down. He helped Wang expand upon his two broad research objectives ("to understand ways that blockchain can improve the security of IoT from a theoretical perspective" and "to assess the feasibility of this theory based on real-life cases") by providing suggestions to select a more focused course of study. LGZ helped Wang reflect on a path forward: "You need to be clearer on which of the multiple aspects of improvement you will focus on. Perhaps ask yourself which will have the greatest impact on the future of IoT? Will it be on trust – if people trust a system, are they more likely to use it? Or data availability – if information is more readily available, how will that increase your user adoption?"

In his final paper, Wang acted on these suggestions. His research question is much more pointed: "If we combine IoT with blockchain, which has built-in securities such as inalterability, will this significantly improve the confidentiality, integrity, and availability of IoT user data by introducing a unique and tailored architecture?"

Wang clearly benefited from the assessment provided by his peer review. He followed his partner's advice, narrowing a broad topic to one that was focused and manageable, and thus targeted specific aspects of blockchain that he felt were most impactful.

Bentley Student Project by Matthew Burns: Public Records Management

The third student project explored the potential benefits of using blockchain to improve the management of public records (Cumming & Findlay, 2010) in the context of property record-keeping and conveyance in the United States. Burns conducted this research using the case method from an interpretivist perspective (Walsham, 1995). Specifically, Burns performed an in-depth analysis of two cases to understand similarities and differences in how blockchain technology was utilized in each case.

In the first case, deeds were recorded in South Burlington, Vermont (De, 2018) in the traditional way (on paper) with the following added to the deed: The disclosure that "This conveyance has been recorded in smart contract 0x… of the public Ethereum blockchain" and a QR code referring to the deed's location on the Ethereum blockchain. Thus, the transfer of property was still recorded on paper and signed by the Chittenden County Clerk and a Notary Public [see Appendix E, Figure 7 (a), for an example].

In the second case, Cook County Illinois created and updated "digital property abstracts" for approximately 2,000 vacant properties scheduled for demolition in the Chicago area. This project required consolidating and reconciling property information that was fragmented across numerous government offices. These digital abstracts were entered on the Bitcoin blockchain. The consolidation of property information enabled the creation of a public-facing portal called *Property Health*. This portal allows potential buyers to search for land or homes and better understand the health of a property, and let them know if they should proceed with caution. A visual of the *Property Health* portal for Cook County can be found in Appendix E, Figure 7 (b). Yarbrough and Mirkovic (2017) summarized the findings and results of the Cook County Recorder of Deeds (CCRD) blockchain pilot project in four "Result" bullets as follows:

1. Participants designed a framework for the first legal blockchain conveyance in Illinois (and possibly the US).
2. CCRD successfully used components of blockchain technology (file hashing and Merkle trees) to secure government records.
3. CCRD used the concept of 'oracles' to build the most informative property information website in Cook County, with a dedicated landing page for each parcel.
4. CCRD's current land records vendor, Conduent (formerly Xerox/ACS) agreed to incorporate some of the technology used in blockchains into the new land records system currently being installed at CCRD. (Yarbrough & Mirkovic, 2017)

The most striking similarity between these two cases was the benefit provided by a collection of records that were secured, verified, and indexed by a blockchain. By deconstructing these two cases, Burns concluded that there was an opportunity for property record-keeping and conveyance in the U.S. to be managed using shared services (Fishenden & Thompson, 2012) provided at the state level. This would allow municipalities or counties to function as peers on a common blockchain, sharing both the benefits and cost of using a "blockchain-as-a-service" (Cachin, 2016). Furthermore, other types of assets, for example, automobiles, motorcycles and boats, could be registered (or recorded) and conveyed using the same service-oriented infrastructure at the state level (Reed, 2010).

Peer Assessment and Discussion

Burns' peer, JG, provided comments early on regarding his research methods (interviews) and benefits to be gained from conducting them, as well as the quality of primary and secondary sources, which "can provide … valuable information regarding connections that can be made between blockchain and governments around the world."

JG identified claims that Burns might wish to clarify moving forward, such as why "vulnerability to fraud and tampering" is a risk but "safeguarding is a benefit," justifying his concerns with his own insights. JG evaluated Burns' approach and whether he thought his research goals were reasonable given constraints of time and resources.

Burns assessed his own learning as he reflected on his interview with a city clerk involved in a blockchain pilot program. He said, "I was able to gain a better understanding regarding the success of this pilot program. I asked about any identifiable efficiencies that blockchain brought to the table throughout the pilot program, namely around time, cost, and security" (which was reflected in his modified research question, as suggested by JG) and then summarized the response.

That Burns considered the feedback and comments from JG is evident in the organization of his final paper. Burns' final paper presented overviews of blockchain technology: an introduction, public vs. private blockchains, smart contracts, and other topics prior to a case study analysis of districts using blockchain technology in governmental practices, specifically land registry and property record keeping transactions.

Bryant Student Project by Team Moscowicz: Smart Contracts

The final student project described in this paper consisted of a hands-on development exercise to build and deploy a smart contract based on the Ethereum blockchain.

Students who opted for the smart contract project were tasked with becoming familiar with the Solidity programming language through a set of free tutorials aimed at creating a CryptoZombies game (see http://www.cryptozombies.io). CryptoZombies is a free, hands-on set of tutorials for those who are new to developing in the Solidity programming language. No software is needed to install since the tutorials' development environment is a hosted solution, allowing students to code and test directly on the CryptoZombies website.

The CryptoZombies tutorials emphasize the difference between fungible and non-fungible tokens (ERC-20 versus ERC-721). With fungible tokens, each token is identical. These tokens have no characteristics that make them distinguishable from one another. With non-fungible tokens, each token has unique attributes which allow for the potential of varying values amongst the tokens (see http://www.erc721.org). Through the CryptoZombies tutorials, the students create a smart contract that can create new Zombies. These zombies have attributes that are often thought of as the DNA of the token. This allows each zombie to be unique.

After completing the tutorials, Moscowicz and his teammates initially decided to develop a smart contract for a complex gambling site. After several weeks of working on this project, they decided that they simply didn't have the skills needed, nor the time to gain the skills, to complete this ambitious effort.

Instead they opted to create a smart contract that was more in-line with what they learned in the CryptoZombies tutorials. What emerged was the Crypto Ice Cream Shop (see Appendix F, Figure 9). The intent was that each "ice cream cone" would be unique (i.e., non-fungible) with different elements of the "DNA" representing the flavor, toppings, cone choice, etc.

The students were responsible for finding and setting up their own development environments. After several attempts using different IDEs, Team Moscowicz settled in with using Remix as their IDE and MetaMask as their test wallet.

Remix allowed for the testing of the smart contract and, by utilizing the Ethereum Ropsten test network, they were able to see the execution of their currency exchange through the website http://ropsten.etherscan.io.

In the end, the team was able to deploy a basic smart contract that generated a non-fungible ice cream cone. They were able to execute the contract (see Appendix F, Figure 10) and see the transaction on the Ropsten test blockchain along with the test fees moving from their MetaMask test wallet (see Appendix F, Figure 11 and Figure 12).

Discussion

With Solidity being a new programming language, online resources to support the students were lacking. Each smart-contract team struggled with simply setting up an environment in which they could develop and test their smart contracts. Through the weekly status reports, teams were able to share lessons learned which helped other teams get past technical hurdles.

While each Solidity project had skilled coders, they were used to programming in a mature language (e.g., Python, Java, etc.) with plenty of examples readily available. In general, the smart contract-teams were frustrated with the lack of resources to help them with their development. Each team frequently evaluated the scope of the project and whether they would be able to deliver a working solution at the end of the semester. In some cases, including this ice cream shop example, projects were abandoned or dramatically changed to account for the unanticipated challenges when working with an emerging technology.

5. LESSONS LEARNED AND CONCLUSIONS

To facilitate PjBL, the courses at Bryant and Bentley were delivered in a format in which the instructor designed activities and assignments to challenge students to apply their understanding of blockchain technologies in areas that supported their projects. These activities and assignments were also designed to pull students out of their comfort zones and to provide an appropriate mix of motivation and frustration (Weimer, 2013). Motivation was needed so that every student successfully completed a significant project. Most frustration was because PjBL centered on a significant project was challenging for many students.

At Bryant, self-regulated learning provided a learner-centered process by which knowledge discovery occurred in areas related to an emerging technology. This helped students bridge their conceptual understanding of blockchain with hands-on activities building components of a decentralized application (dApp). Adaptation occurred as students struggled to translate their conceptualization of blockchain into action (Weimer, 2013).

At Bentley, peer feedback had a positive influence on students' final projects. Students worked in pairs to review each other's abstracts, research questions, goals, methods, and sources, and offered recommendations for improvement. The process of peer assessment allowed students to reflect on what they had learned, apply their knowledge, review the work of a partner, articulate their own insights, draw conclusions, and to provide constructive criticism and suggestions (Reinholz, 2016). Exchanging feedback with their partners empowered students to be teachers and learners of blockchain-focused knowledge and skills.

While PjBL, self-regulated learning, and peer learning are not new concepts, this case study highlights the benefits of each in relation to learning about an emerging technology. At both Bryant and Bentley, these teaching methods extended student understanding of blockchain to new domains, gave audience to the students' work, and enabled students to learn from each others' insights. Furthermore, reflection, and the sharing of that reflection with others, helped everyone in our classes gain a more in-depth understanding of blockchain technology and how it might be used. Emerging technologies, however, may lack clear and consistent resources. It is often left to the instructor to try to answer all of the students' questions. However, having a community of students develop the skills to answer their own questions – after some research – and solve their own problems gave most students the confidence to learn and apply the emerging technologies that lie over the horizon.

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Appendix A. Blockchain and the Hype Cycle for Emerging Technologies

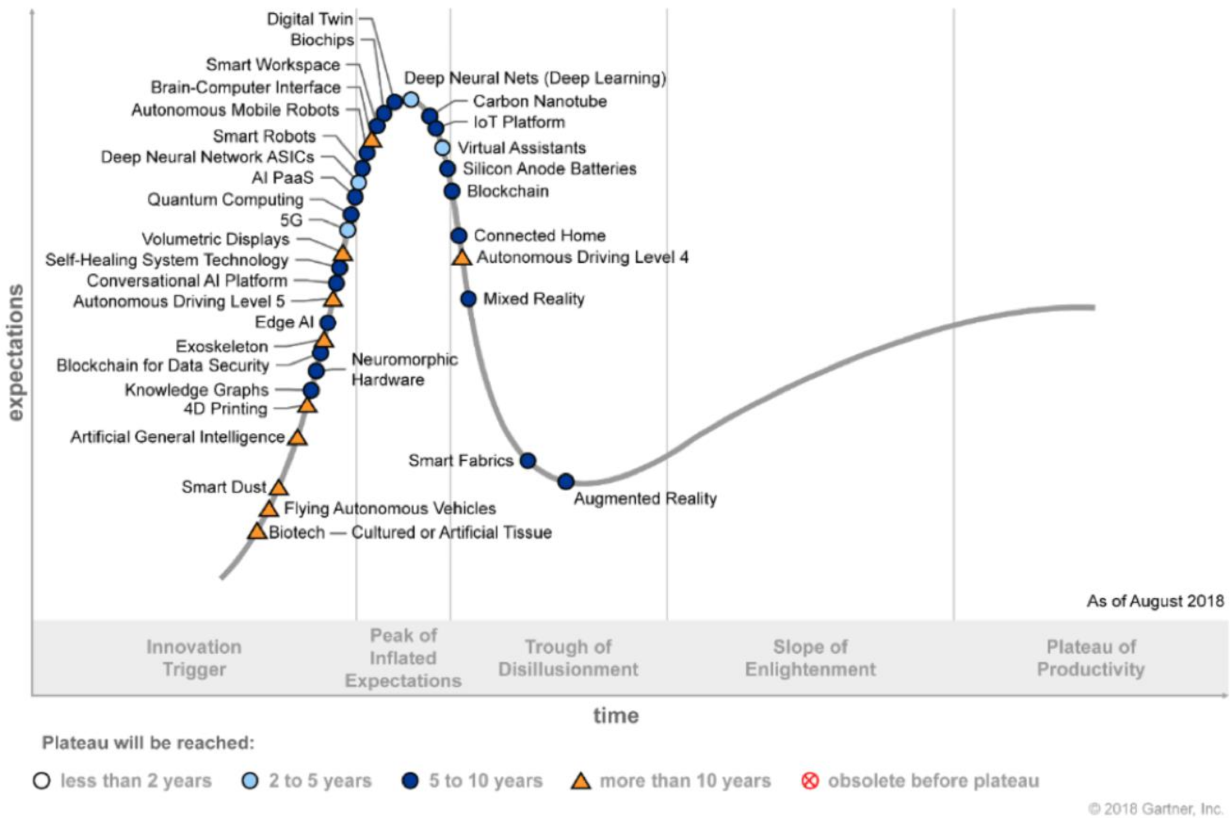

Figure 5. Blockchain is past its peak in the Gartner hype cycle for emerging technologies [Source: (Gartner, 2018)]

Appendix B. *Introduction to Blockchain* at Bryant University

Introduction to Blockchain at Bryant was a 400-level special topics course aimed at seniors in an undergraduate program taught in the spring of 2019. Most students only had a vague idea of what blockchain was when they started the class.

The first half of the semester was focused on student understanding of blockchain, its terminology, the difference between the technology and its applications, and what it means to be a "miner." During this time the students were each given a Raspberry Pi to create their own mining device, which required them to gain the skills and basic knowledge of crypto-mining and digital wallets. This was worth 10% of their grade as shown in the syllabus below.

The midterm exam (20% of the grade) was formatted in a way to mimic the format of the Blockchain Architecture exam given by the Blockchain Training Alliance (see http:///www.blockchaintrainingalliance.com). This tested the fundamentals and basic terminology of blockchain.

The students then had to demonstrate that they understood the potential applications of blockchain by writing an industry-focused midterm paper (20% of the grade) in an industry of their choice.

The course then split into two paths. Students could take a technical (i.e., development-oriented) path by designing and developing their own smart contract in Solidity, or a research path by expanding on their industry paper through a mini-research project in that domain.

Students provided status reports (included as part of the 20% class participation grade) to the class once a week for the remainder of the term. This allowed students to share their forethought and goals for the week, an assessment of how well they achieved those goals, and a self-reflection on how well the work towards these goals was executed.

While the instructor provided the initial instructions, along with expectations appropriate for self-regulated learning (Saks & Leijen, 2014; Stefanou & Stolk et al., 2013), the students relied on the process of forethought, performance, and self-assessment (Zimmerman, 1990) to accomplish this project (30% of the grade). A central component of self-regulated learning in this course was the choice that the students had during week nine – to complete the course via either the developer track or the research track. (These tracks are summarized in the *Course Description* below.) A comparison of the projects by D'Amico and Moscowicz and his teammates, in Section 4, provide illustrative examples of how important this choice was for the students. Since project-based learning typically demands that the faculty member's role is that of an advisor to the students rather than an instructor, the first author yielded control of this choice to each student, but required that their first step in either track was to submit and receive feedback on a proposal.

Course Syllabus, Spring 2019
ISA ST400 Introduction to Blockchain

<u>TEXTBOOKS AND OTHER RESOURCES</u>

1. Bambara, J. J. & Allen, P. R. et al. (2018). *Blockchain: A Practical Guide to Developing Business, Law, and Technology Solutions.* McGraw Hill Education (ISBN 978-1260115871) **Required**
2. Bennet, K., Rieger M., & Lee E. (2018). *Certified Blockchain Solution Architect: Official Exam Study Guide.* Blockchain Training Alliance (Available from www.blockchaintraining alliance.com). **Optional – On Reserve in Library**
3. Weisner, T. & Lee E. (2018). *Certified Blockchain Developer Ethereum: Official Exam Study Guide.* Blockchain Training Alliance (Available from www.blockchaintraining alliance.com). **Optional – On Reserve in Library**

RATIONALE

Blockchain is being discussed as a serious disruptor across vast industries. We have seen cryptocurrencies, built on blockchain technology, surpass the GDP of many countries, thus leading some governments to suggest replacing their own currency with a new cryptocurrency. Venezuela is one such country, having launched the cryptocurrency Petro to supplement their plummeting currency the bolivar.

With the advent of *smart contracts*, or the ability to embed logic in with the blockchain transaction, a new crop of applications (called dApps or decentralized applications) has emerged. Success has already be achieved in the areas of gaming (CryptoKitties), betting or futures prediction (Auger), identity management (uPort), and computing power sales (golem), just to name a few.

Cryptocurrencies have been of keen interest to public safety, as we have seen Bitcoin used as the currency of choice in illegal activities such as drug and arms sales. By hiding behind the anonymity afforded by the cryptocurrency, people are engaging in transactions that otherwise would have been more difficult.

These smart contracts present enormous opportunity, as well as heightened risk. We have seen poorly designed smart contracts lead to enormous financial loss. Unlike traditional software development, rolling out a smart contract with a bug can wreak havoc financially, due to the inability to easily change contracts and the inability to reverse transactions.

This course will provide students with a) a full understanding of the blockchain technology with the understanding of why companies are choosing this technology as their platform and b) the ability to develop smart contracts based on the Ethereum blockchain. The course will involve hands-on instruction, using the Solidity programming language, to implement a simple smart contract in an Ethereum training environment.

This course will prepare students to take the BTA Certified Blockchain Solution Architect (CBSA) exam for an industry recognized certification in the field of blockchain.

COURSE DESCRIPTION

This course introduces students to blockchain technology. The first half of the course will be used to gain a full understanding of the technology from a management perspective. Students will gain the knowledge needed to understand where this emerging technology is being used and explore why companies are choosing to build their business on blockchain. Students will gain an appreciation of the different types of blockchain with discussion around when each is appropriate to implement. We will explore many industries to understand the global nature of blockchain and begin to see the value in implementing blockchain in many vertical markets including supply chain, finance, gaming, and government, just to name a few.

Students will choose a path to pursue shortly after the midterm exam and once everyone has a general understanding of solidity. There are two paths – the Developer Path and the Research Path.

Developer Path: The second half of the course will be hands-on with the students developing their own smart contract. The students will learn the Solidity programming language in order to write their own smart contracts. Existing smart contracts will be used to discuss techniques and ways to organize code. Students will deliver weekly status reports, including hands-on lessons-learned to the other Developers. These status reports are intended to a) keep the project moving forward and b) share knowledge with the other teams in order to help others overcome technical hurdles. We will deploy the smart contracts in a private Ethereum environment so students understand the full development lifecycle.

Research Path: The second half of the course is devoted to developing the "industry paper" into a full-fledged research paper. Students will propose how they intend to add new knowledge to the field of blockchain beyond their industry paper. In most cases this will be through the gathering of data (survey data, social media data, interviews, etc.) and the reporting of the findings. Students will deliver three presentations to the entire class. The first presentation is to explain to the class how they intend to pursue their research. This will include research objectives and potential data sources.

The two subsequent presentations are to give updates to the class in order to a) motivate the team to keep moving forward and b) brainstorm on data gathering techniques, should hurdles be met. This would also be a good time for a team to distribute a survey to the class if survey data can be used in the research topic. The final deliverable is a research paper.

Prerequisites Any course with a programming component

Learning Goals The learning goals and objectives of this course are as follows:

1. To enable students to develop knowledge, skills, and understanding around a range of subjects in the field of blockchain.
2. To enable students to evaluate and develop smart contracts using the Solidity language (technology or developer track).
3. To enable students to apply concepts and principles from various industries to understand blockchain opportunities.
4. To enable students to recognize the unique challenges of implementing blockchain including inability to easily change smart contracts and the inability to reverse transactions.
5. To enable students to effectively interpret and communicate their ideas through written and oral reports (emphasized on research track).

Program-Related Learning Goals

1.2.A. Students will demonstrate effective writing for business.

1.2.B. Students will demonstrate effective oral communications in business situations.

1.2.C. Students will use multimedia to support effective presentations.

2.1.B. Students will demonstrate critical thinking skills by analyzing complex problems and recommending feasible solutions.

2.2.B. Students will use information technology to formulate, analyze, and solve business problems.

6.1.E.a. Describe the concepts, procedures and tools necessary for building a computer-based information system.

6.1.E.b. Use technology to analyze data and solve real-life business problems.

Student Evaluation The criteria used to evaluate students will be:

Cryptocurrency Mining	10%
Mid-term Exam	20%
Smart Contract Project OR Research Paper	30%
Industry Paper	20%
Class Participation / Assignments	20%
Total	100%

Grade	Point Range
A	92.5-100%
A-	90.0-92.4%
B+	87.5-89.9%
B	82.5-87.4%
B-	80.0-82.4%
C+	77.5-79.9%
C	72.5-77.4%
C-	70.0-72.4%
D+	67.5-69.9%
D	60.0-67.4%
F	0-59.9%

Class Participation Every member of the class is expected to participate in every class. Participation is one of the major keys to active learning. Each student will be judged on the quality and quantity of participation in class discussions. I expect students to be interactive in the class. Contributions that add new insights or advance the discussions, including clarifying questions, will be rewarded. An evaluation will be performed at the end of the semester.

Students are not allowed to leave class early except with permission of the instructor. If permission is not obtained, it will count as a class absence. In addition, failure to sign the attendance sheet will count as a class absence.

Assignments and Projects The student will work on multiple assignments throughout the semester including homework that will target specific blockchain understanding (industry research, blockchain inspection, smart contract analysis, etc.). Each student will have a mid-term research paper that will either be broad (analyze how blockchain is impacting a specific industry) or deep-dive (analyze a specific blockchain implementation). Students will have their choice for a final project. The student can choose between a technology track (developing a smart contract using Solidity) and a research track (writing a final paper for a specific market). All assignments are to be done individually unless otherwise stated.

Exam The exam will be based on the Blockchain Training Alliance Blockchain Solution Architect Exam for blockchain certification. Students can optionally take the exams through the Blockchain Training Alliance which will give them an industry recognized blockchain certification – Students will be responsible for the extra cost (currently $300 per exam) associated with this certification if they choose this option (see: https://blockchaintrainingalliance.com/pages/blockchain-certification). Any student who takes the BTA exam and scores a passing grade (thereby becoming "certified") will automatically receive an A on the mid-term exam.

Schedule

Week #	Topics		Assignment
1	Introduction to Blockchain		Intro to Blockchain Slides
2	Blockchain Fundamentals *Industry Application: Cryptocurrencies*		Mining Proposal
3	Deciding to Implement Blockchain *Industry Application: Finance*		Discussion Post: Finance
4	Introduction to Distributed Applications (dApps) *Industry Application: Supply Chain*		Discussion Post: Supply Chain
5	Designing dApps *Industry Application: Gaming*		Discussion Post: Gaming
6	Challenges Associated with dApps / Testing dApps *Industry Application: Government*		Discussion Post: Government
7	Project Presentations		Industry Paper Mid-term Exam
8	Ethereum Basics		
9	Introduction to Ethereum Programming		Smart Contract Proposal OR Research Proposal
	FORK – Students decide programming track or research track		
	Developer Track	**Research Track**	
10	Solidity Basics – Status Update #1	Proposal Due	
11	Solidity Basics	Literature Review	
12	Solidity: Advanced – Status Update #2	Proposal Presentations	
13	Solidity: Advanced	Status Report #1	
14	Contract Security and Testing – Status Update #3	Status Report #2	
15	Smart Contract Presentations	Research Paper Due	

Appendix C. *Blockchain: Applications, Policy and Implications* at Bentley University

The blockchain course offered at Bentley was an undergraduate honors capstone course taken by advanced students from a variety of business-oriented majors. This course provided students with conceptual frameworks, methodologies, and analytical tools (Saunders, Lewis & Thornhill, 2016) for the study of blockchain technology and its applications and implications. The final deliverable in this course was an individual research project in which each student made an original research contribution based on blockchain technologies.

One of the more challenging dimensions of project-based learning for many instructors is yielding control over the design of the most important learning experience, i.e., the project, to the student (Brookfield, 2017; Freire, 1993; Kember & Gow, 1994). Brookfield (2017) carries this idea further and suggests that in many situations instructors can empower and motivate students by having them specify intermediate milestones, grading percentages, due dates, etc. At the urging of the students in this HNR 440 class, such a conversation occurred during week two of class (i.e., on September 5). This conversation resulted in three important changes to the syllabus shown below: First, the students had three chances to refine their research questions (noted as Take 1, Take 2 and Take 3 below). The order of the *project proposal* and *critical literature review* was reversed. And the weight of the final paper was reduced from 45% of the course grade to 25%, spreading the remaining 20% to other intermediate milestones.

The syllabus for this course, which was finalized after week two, is shown below. The research project counted for 80% of the course grade. Breaking down this 80%, 45% of each student's grade was based on four intermediate milestones, and a final presentation and final paper counted for 35% of their grade. Together with one-on-one meetings with each student, these milestones encouraged iterative and incremental development of the projects.

Recall that a critical component of this project-based course was peer feedback, including peer assessment. Activities and assignments to challenge students to apply their understanding of blockchain technologies to their project and their peer's project accounted for the remaining 20% of the course grade.

Peer assessment is a set of activities through which individuals make judgments about the work of others – often students enrolled in the same course – to confer and provide feedback about each other's work. In the Bentley course, the most rigorous peer assessment was the third assignment, which was due during week four of the semester; on September 19 in the fall 2018 syllabus below. Appendix D presents this assignment (Assignment 3). And the discussion of two Bentley student projects in Section 4 includes an analysis of how the peer assessments provided to Wang and Burns both influenced and improved their final projects. Furthermore, much of the in-class discussion focused on challenges and opportunities that the students experienced as they worked on their research (Brookfield, 2017; Thomas, 2000). This discussion led to students relying heavily on giving feedback to and receiving feedback from each other. Furthermore, respectful peer feedback and constructive peer assessment forged a sense of community among the students (Freire, 1993) that developed quickly and remained strong throughout the semester.

Honors Capstone Course Syllabus, Fall 2018

HNR 440/445 Blockchain: Applications, Policy and Implications

Rationale: Because blockchain has the potential to be disruptive in so many different sectors, it can be studied from different perspectives, e.g., economic, political or social. Since blockchain began as one of the important technologies that underlies Bitcoin and other cyptocurrencies, its first use cases were to mediate payments, which subsequently led to blockchain's early adoption in financial services. More recently blockchain has been proposed for applications as diverse as supply chain management, health record management, land and deed registration, and voting. These very different use cases means that blockchain – and its associated applications, policy or implications – can be examined either in the context of a single discipline, e.g., accounting, finance, computer information systems, or at the intersection of several disciplines, e.g., economics, public policy, and law.

Perhaps the most exciting 'killer app' for blockchain is *smart contracts*. According to *Wikipedia*, a "smart contract is a computer protocol intended to digitally facilitate, verify, or enforce the negotiation or performance of a contract." In other words, a blockchain can be decentralized system that serves as on-line intermediary between parties, providing faster, cheaper, more secure, and more predictable contract (or transaction) execution than traditional systems. Hence the significant interest in blockchain technology within both the public and private sectors. However, because smart contracts are multi-party entities, study and research in this area often requires a multi-stakeholder approach.

Library Resources: These books are on reserve in the Bentley library –

Bashir, I. (2018). *Mastering blockchain: Distributed ledger technology, decentralization, and smart contracts explained* (2nd ed.). Packt Publishing.

De Filippi, P., & Wright, A. (2018). *Blockchain and the law: The rule of code*. Harvard University Press.

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Norman, A. T. (2017). *Blockchain technology explained: The ultimate beginner's guide about blockchain wallet, mining, Bitcoin, Ethereum, Litecoin, Zcash, Monero, Ripple, Dash, IOTA and smart contracts*. CreateSpace Independent Publishing.

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2016). *Research methods for business students* (7th ed.). Pearson Education.

Course Description: This capstone project course provides students with conceptual frameworks, methodologies, and analytical tools for the study of blockchain technology and its applications, policy and implications. Why is there so much hype around blockchain? Anything that you can create a record for and enter in a ledger, you can manage with a digital blockchain. Furthermore, blockchain's processing capability is near real-time, near tamper-proof and increasingly low-cost. Blockchain technology therefore has the potential to be hugely disruptive. It can be used by a wide variety of industries and services, such as financial services, real estate, healthcare, and government, for example.

The course has the same objectives as the individual honors capstone project. During the course, students will be required to read, discuss and analyze a multitude of readings (peer-reviewed articles, book chapters, practitioner articles, industry reports, etc.). The final deliverable is an individual research project in which the student will focus on a particular aspect of blockchain – applications, policy, implications, technology, etc. – and make an original research contribution. Students are encouraged to identify a topic of interest within this broad area and to develop their own research questions, consistent with their interests and academic strengths. The instructor will offer guidance regarding the appropriate research methods and theoretical perspectives for the project.

We will begin the semester with regular class meetings and then to move to independent work and one-on-one meetings with your faculty advisor (i.e., the course instructor) with periodic group meetings to share information, provide feedback on each other's work, and assist each other in overcoming any challenges. The course will address broader themes in the earlier weeks of the semester, which might help students identify research questions of interest. Later in the semester, students will focus on their research projects.

This capstone course will count as either a Business Elective (HNR 440) or A&S Elective (HNR 445), and many topics lend themselves to integrating students' business and arts & sciences education with an interest in blockchain technology and its applications, policy or implications.

Additional assigned articles and material will be available through the course's Blackboard site or Google Drive.

Prerequisites: An understanding of quantitative and qualitative research methods and good standing in the Bentley Honors Program.

Learning Goals:

1. Understand and describe common use cases and emerging applications that are based on blockchain technology.

2. Understand and analyze policy, legal, and regulatory challenges posed by blockchain (Werbach, 2018).
3. Design distributed applications based on blockchain and explain critical design decisions.
4. Learn how to formulate a tractable research question and determine how to answer it.
5. Design and execute a novel and significant research project from initiation to manifestation and public presentation.

Course Requirements:

Participation:	10%
Assignments:	10%
Project critical literature review:	12%
Project proposal:	10%
Project progress report I	8%
Project progress report II & analysis:	15%
Presentation:	10%
Research Paper:	25%

Participation: Every class session will consist of discussion of one or more of the following:

- Blockchain concepts relevant to applications, policy or implications
- Research methods
- Current events related to blockchain

All students are expected to participate in these discussions and be able to elaborate on their viewpoints.

Project Critical Literature Review: Provide a critical literature review of the previous academic research on your research topic (i.e., a literature review). What are the areas of consensus and controversy in this previous academic work? What are the substantive and methodological shortcomings? This review should end by reaffirming or refining the research question(s) and research objectives that you developed as part of your first three assignments. [Research question(s) and research objectives, Take 2.]

This literature review should be a synthesis of a number of sources organized in a thematic manner. It is not a summary of each article in turn. The sources that you use for this review typically should include at least at least 15 scholarly articles and possibly one or two scholarly books. The balance between books and articles may be different for certain subject areas, however. For most projects in a rapidly evolving area like blockchain applications, policy or implications, more than half of your sources should have been published in the previous five years. This section should be approximately 2,500 words in length including in-text citations.

Project Research Proposal: Each student will prepare an eight- to twelve-slide presentation that presents:

- Research question(s) and research objectives, Take 3
- Method
- Timescale
- Research philosophy and research approach
- Research strategy
- Research methodology

and an associated research paper proposal (1,000 words) the covers the same areas.

Project Progress Report I: Each student will hand in a 1,000-word progress report and present his or her progress with a single slide in class. The student will refer to his or her original proposal, address any new or revised research question(s) or research objects, give an update of the research process and research progress.

Project Progress Report II & Analysis: Each student will hand in a 1,500-word progress report and present his or her progress with two slides in class. The student will refer to his or her original proposal, address any new or revised research question(s) and research objectives, give an update of the research process, and introduce an overview of his or her analysis of the research topic.

Final Presentation: Students will present their paper in a formal 10 minute long Power Point (or similar presentation tool) presentation. A question & answer session will follow. Instructions for completing the presentation will be distributed during the course.

Final Research Paper: Each student will write a research paper (their 'honors' thesis) in the form of a 'publishable' journal article. Instructions for completing this paper will be distributed during the course. The paper for this course will be around 8,000 words (standard journal article length). The paper will require the use of outside resources. Students MUST cite any and all sources used. All assignments will be submitted though Blackboard. No deadline extension will be offered. Papers handed in after the specified time will have ten percent subtracted from their final score for each day they are late.

Tentative Course Schedule:

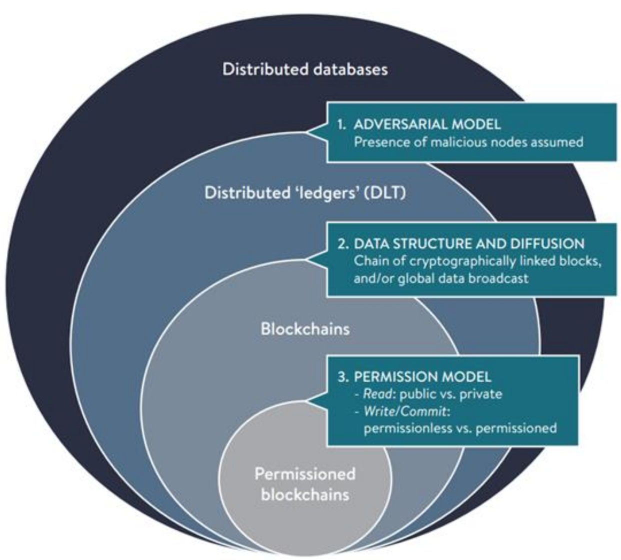
WEEK	**THEME**
Aug 29	Introduction to the Course, Blockchain overview
Sep 05	**Abstracts on Projects due Sep 04 at 11:59 PM** Discussion of projects based on abstracts
Sep 12	**Project Overview Presentations due Sep 11 at 11:59 PM** [Research question(s) and research objectives, Take 1.] Blockchain, Applications, Policy and Implications overview
Sep 19	Library Resources and Project Planning **Peer Project Feedback due Sep 21 before 11:59 PM**
Sep 26	The Role of Trust in Blockchain
Oct 03	**Project Critical Literature Review due before 6:29 PM**
Oct 10	One-on-one meetings
Oct 17	Blockchain Case Study: CryptoKitties and Ethereum **Project Research Proposal due before 6:29 PM**
Oct 24	Project consultations **[mandatory]**
Oct 31	**Project Progress Report I due before 11:59 PM**
Nov 07	One-on-one meetings
Nov 14	Project consultations **[mandatory]** **Project Progress Report II & Analysis due Nov 19 before 11:59 PM**
Nov 28	One-on-one meetings
Dec 05	Reflections on Blockchain, Applications, Policy and Implications
Dec 12	**Final Presentations due before 6:29 PM**
Dec 15	**Final Research Paper due before 6:29 PM**

Appendix D. Peer Assessment Assignment

Spend a minimum of 5 hours and a maximum of 7.5 hours on Assignment 3 to conduct a peer-assessment of your partner's Assignment 2 using the seven parts below, i.e., A. through G.

Based on my experience writing up feedback for KM, an alternative way to think about this assignment is to write up the most helpful approximately 2,000 words you can write to advance and improve your peer's project:

A. Is (Are) your peer's research question (questions) clear?
B. What is not clear about their research question(s)? If their research question(s) is (are) 100% clear, that's OK.
C. Does their research question pass Clough and Nutbrown's (2012) 'Goldilocks test', i.e., is it neither too big nor too small?
D. How do their research objectives align with the narrative around and content of Table 2.3 in Saunders, Lewis & Thornhill (2016) [*Examples of research questions and related research aims*]?
E. How many secondary sources did your peer find?
F. Find three additional secondary sources for their project and list them in APA format.
G. Provide written feedback to your peer with respect to two aspects of their revised abstract:
1. Is the motivation for their research project clear?
Assignment 1 revisited [see Figure 6 (b)]: Why is the topic of interest to business or consumers [or both] (for private sector projects) or to governments or citizens [or both] (for public sector projects).
2. Did they answer the 'Why blockchain?' question?
Assignment 1 revisited: Consider benefits, risks and implications of using blockchain motivated by applications or use cases that are well suited to blockchain. Consider this carefully in the context of the "distributed databases" technology hierarchy slide we covered in the slides of September 12:



Source: Global Blockchain Benchmarking Study (Hileman & Rauchs, 2017)

Figure 6 (a). Specification of the peer assessment Assignment 3 from Bentley University

Abstract for your Research Project, 250 words maximum

By being so concise, this is a “less is more assignment” designed to focus your time and energy on a research topic that you can start and finish by mid-December with minor, but not major, modifications along the way.

Your abstract should explicitly do three things:

1. Identify a right-sized topic area for your research project.
   (Hint: Right-sized topic areas are usually smaller than you think.)
2. State the motivation for your research project:
   Why is the topic of interest to business or consumers [or both] (for private sector projects) or to governments or citizens [or both] (for public sector projects).
3. Answer the ‘Why blockchain?’ question:
   Consider benefits, risks and implications of using blockchain motivated by applications or use cases that are well suited to blockchain.

If it’s helpful to address the methodology or approach in the first draft of your abstract, please do so. If it’s not helpful, please don’t. Recall that I said in class that it is fine at this point if your abstract is methodology agnostic.

If you need some non-blockchain examples of good abstracts, I have put four research papers on our course blackboard site in Course Documents > Example Abstracts.

Finally, please submit your abstract at the Assignment 1 TurnItIn.com link below.

Figure 6 (b). Specification of Assignment 1 which was revisited as part of Assignment 3

Appendix E. Maintaining Land Records with Blockchain in Chittenden County, Vermont and Cook County, Illinois

00048316 V: 1412 PG: 199

CITY CLERK'S OFFICE
Received Feb 21,2018 11:32A
Recorded in VOL: 1412 PG: 199 -200
OF So. Burlington Land Records
Attest:
Donna Kinville
City Clerk

WARRANTY DEED

KNOW ALL PERSONS BY THESE PRESENTS that **KATHERINE M. PURCELL**, of Burlington, County of Chittenden and State of Vermont ("Grantor"), in consideration of the sum of Ten and More Dollars, paid to her full satisfaction by **KP2 LLC**, a Vermont limited liability company with a place of business in Burlington, County of Chittenden and State of Vermont ("Grantee"), by these presents, does hereby **GIVE, GRANT, SELL, CONVEY and CONFIRM** unto the said Grantee, **KP2 LLC**, and its successors and assigns forever, a certain piece of land with all improvements thereon and appurtenances thereto in the City of South Burlington, County of Chittenden and State of Vermont (the "Premises"), described as follows, viz:

Being all and the same lands and premises conveyed to Katherine M. Purcell by Warranty Deed of Maurilio Fabiano dated March 18, 1988 and recorded in Volume 259 at Page 382 of the South Burlington Land Records, and being more particularly described therein as follows:

"Being all and the same lands and premises conveyed to the within Grantor by Warranty Deed of Stephen B. Jamison and Patricia A. Jamison dated 10/23/85 and recorded in Volume 214, Page 226 of the South Burlington Land Records and being more particularly described therein as follows:

'Condominium Apartment 143, Cluster 6, Twin Oaks Condominium, together with a 3.073 percent interest in the Common Areas and Facilities and Limited Common Areas and Facilities as set forth in the Declaration dated August 20, 1980, of record in Volume 162 at Page 264 of the City of South Burlington Land Records.

Said premises are subject to the Declaration of Condominium for Cluster 6 of the Twin Oaks Condominiums, dated August 20, 1980, recorded in Volume 162, Page 264; the Bylaws of the Twin Oaks Condominium Association, Cluster 6, dated August 20, 1980, recorded in Volume 162, Page 273; and an Agreement and Declaration of Covenants, Conditions, Easements and Liens, dated January 16, 1979, recorded in Volume 143, Page 514, as amended by instruments dated February 20, 1979 and April 9, 1979, recorded in Volume 143, Page 559 and Volume 150, Page 110, respectively, and as confirmed by an instrument dated January 31, 1980, recorded in Volume 157, Page 475. The lands are further subject to Land Use Permits dated October 19, 1979 and November 27, 1979, recorded in Volume 157, Pages 184 and 272, respectively...'

Stephen B. Jamison and Patricia A. Jamison join in the execution of this deed to convey any interest they may have in this premises as a result of a defect in the execution of their deed to the Grantor herein."

The Premises are subject to: (a) taxes assessed on the Grand List not delinquent on the date of this Deed, which Grantee herein assumes and agrees to pay as part of the consideration for this Deed subject to such taxes being prorated between Grantor and Grantee on the date this Deed is delivered; (b) the provisions of municipal ordinances, public laws and special acts; and (c) all easements and rights of way of record, not meaning to reinstate any claims barred by operation of the Vermont Marketable Record Title Act, 27 V.S.A. § 601, *et seq*.

Reference is hereby made to the above-mentioned instruments, the records thereof and the references therein contained in further aid of this description.

00048316 V: 1412 PG: 200

TO HAVE AND TO HOLD the said granted Premises, with all the privileges and appurtenances thereto, to the said Grantee, **KP2 LLC**, and its successors and assigns, to their own use and behoof forever; and the said Grantor, **KATHERINE M. PURCELL**, for herself and her successors and assigns, does covenant with the said Grantee, and its successors and assigns, that until the ensealing of these presents, Grantor is the sole owner of the Premises, and has good right and title to convey the same in the manner aforesaid, that the said Premises are **FREE FROM EVERY ENCUMBRANCE**, except as aforementioned; and they hereby engage to **WARRANT and DEFEND** the same against all lawful claims whatsoever, except as aforementioned.

This conveyance has been recorded in smart contract 0xa188e5a3da203f8ebc72ec7578532926dc1d3bec of the public Ethereum blockchain.

IN WITNESS WHEREOF, the parties do hereby execute this Warranty Deed this 20th day of February, 2018.

Katherine M. Purcell

Katherine M. Purcell

STATE OF VERMONT
COUNTY OF CHITTENDEN, SS.

On this 20th day of February, 2018, personally **KATHERINE M. PURCELL**, to me known to be the person who executed the foregoing instrument, and she acknowledged this instrument, by her signed, to be her free act and deed.

Before me, ______________
Notary Public

Printed Name: Michelle N Farkas

Notary commission issued in Chittenden County
My commission expires: 2/10/19

Vermont Property Transfer Tax
32 V.S.A. Chap 231
-ACKNOWLEDGEMENT-
RETURN REC'D-TAX PAID BOARD
OF HEALTH CERT. REC'D.
VT LAND USE & DEVELOPMENT
PLANS ACT. CERT. REC'D
Return No. ______________
Donna Kinville City Clerk
Date Feb 21,2018

END OF DOCUMENT

Figure 7 (a). Copy of the paper deed registered in Chittenden County (Vermont) used in a property transfer during South Burlington's blockchain pilot

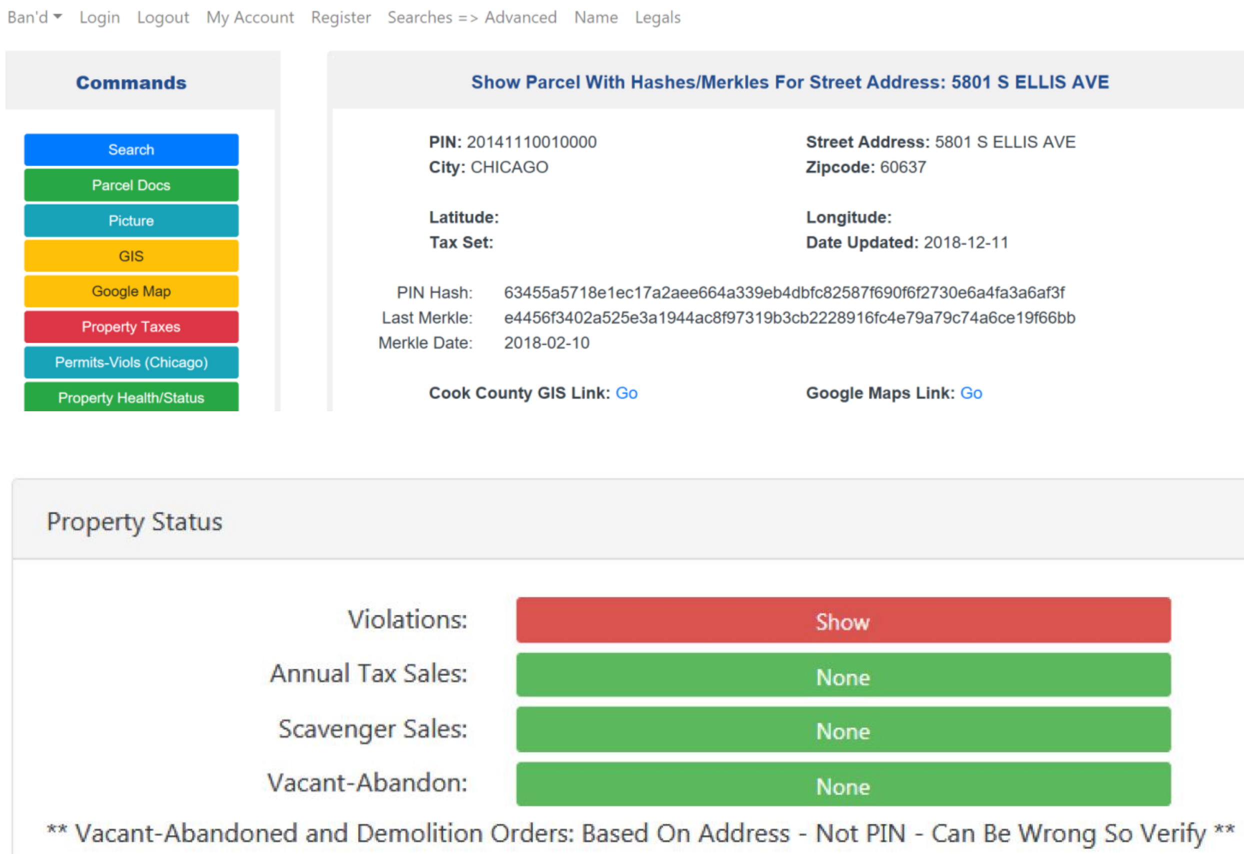


Figure 7 (b). Visual of the *Property Health* portal used in Cook County (Illinois) Recorder of Deeds blockchain pilot

Appendix F. Privacy Concerns for Healthcare Data on a Blockchain and Smart Contracts with CryptoZombies

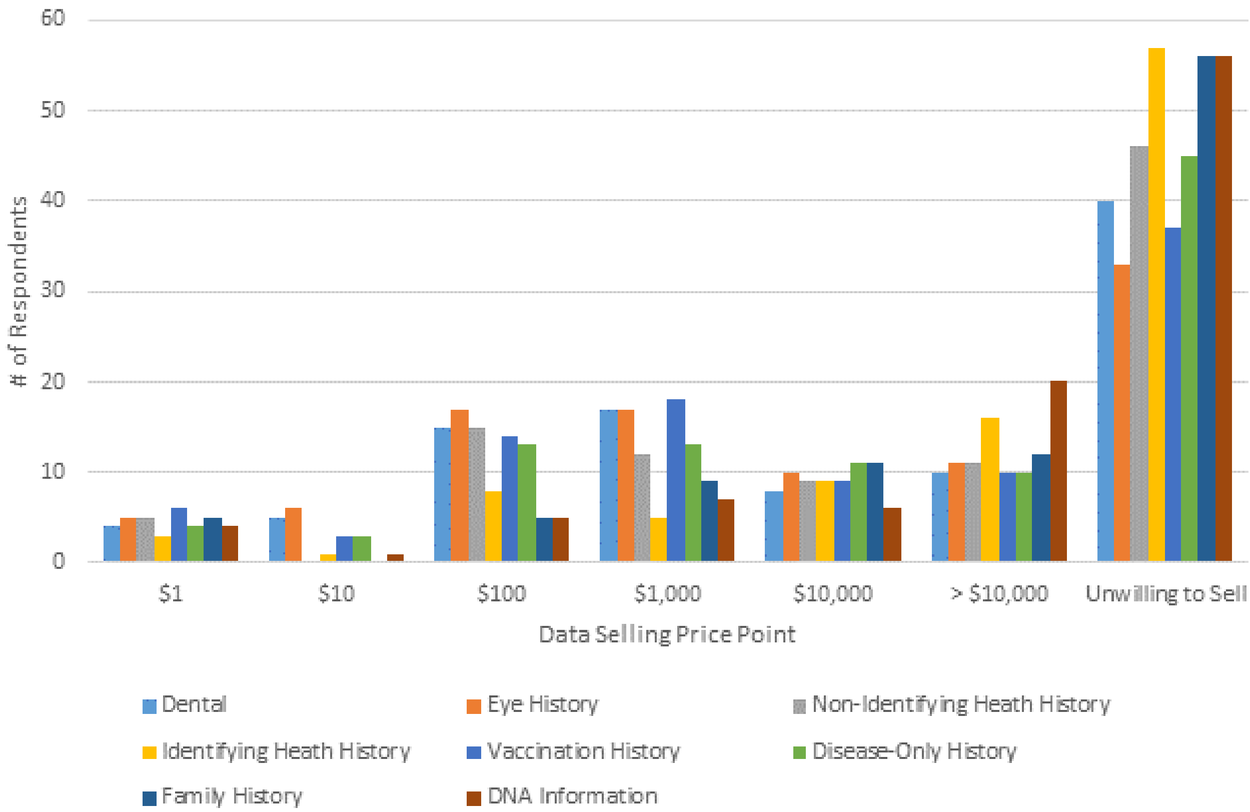


Figure 8. Data sensitivity of healthcare data

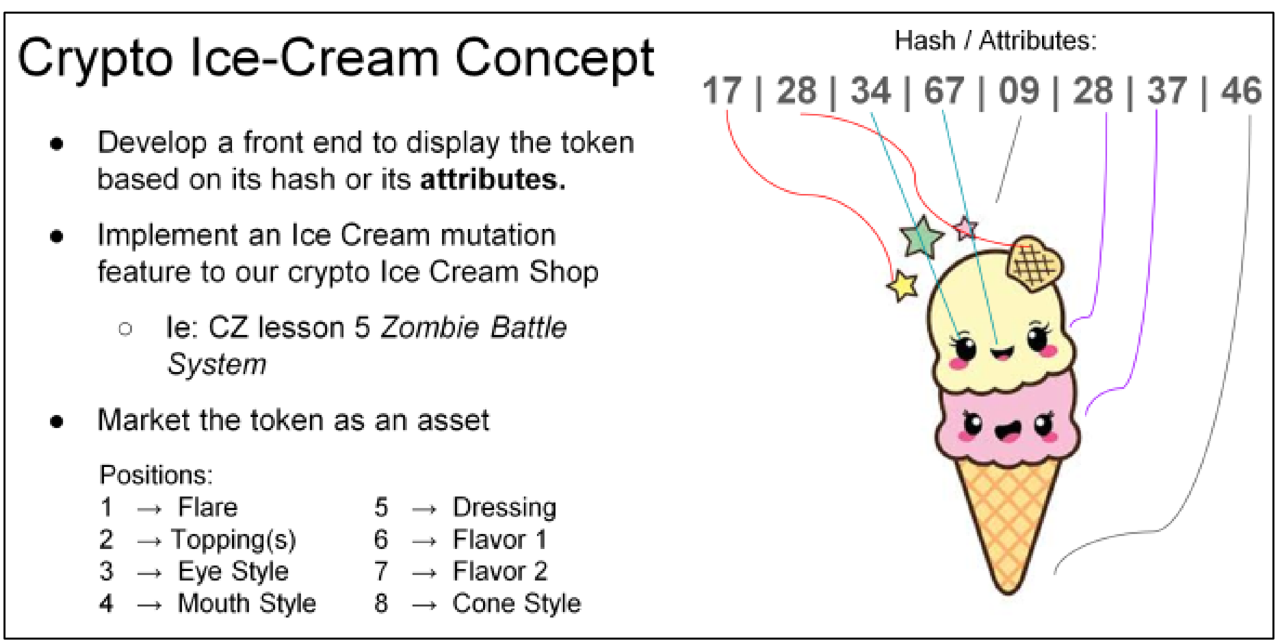


Figure 9. Conceptual design of crypto ice cream shop with example cone

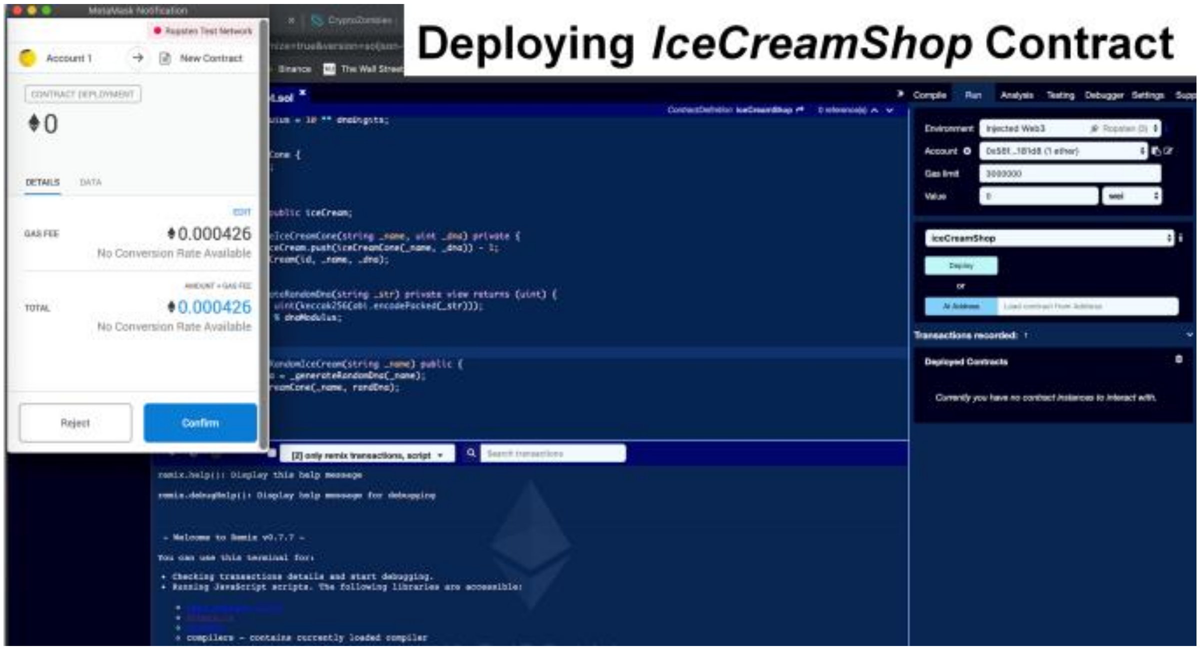


Figure 10. Smart contract deployment screen with transaction confirmation

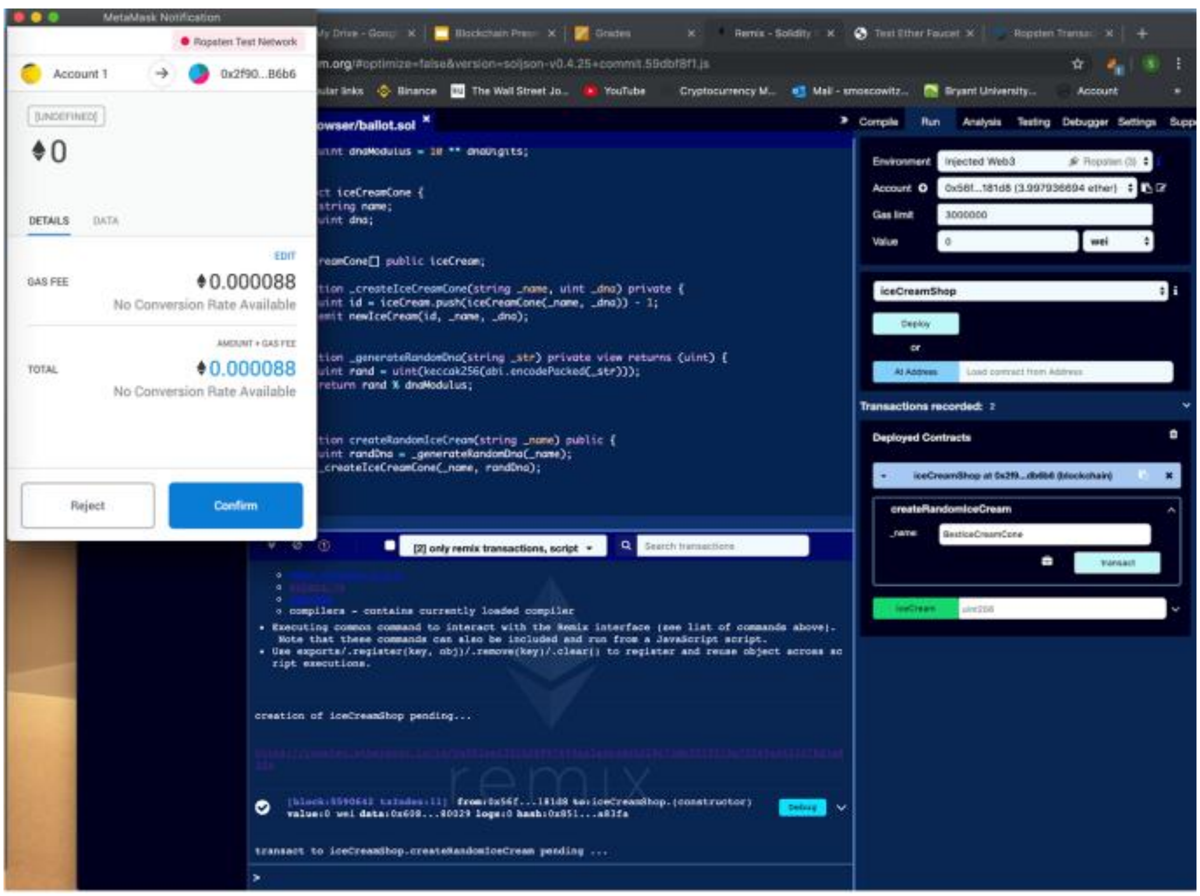


Figure 11. Evidence of smart contract deployment to test environment

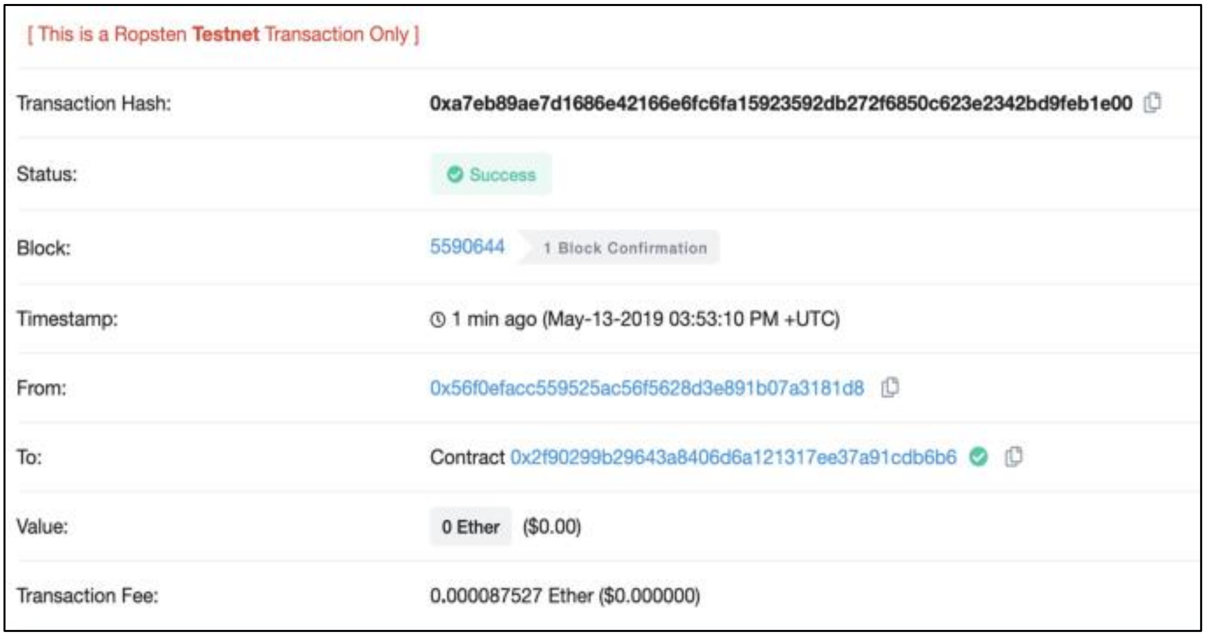


Figure 12. Transaction confirmation on Ropsten test environment

Class Participation and Student Performance: A Tale of Two Courses

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Abstract

Student performance in classes can be affected by lack of attendance and attention while in class. This paper examines the effect of student participation on performance in two Computer Science classes. Attendance and attentiveness are automatically recorded by the videoconferencing software used for the classes. Student participation is measured by multiplying the scores for attendance and attentiveness. In the one class, we found a positive relationship between participation and scores on the final examination. This class is a concepts type class, focusing on theoretical information presented in lecture format. In the other class, we did not find a relationship. This class is a skills type class, focusing on practical skills and involving more hands-on work. The relationship may have been masked by the associated lab and relatively late dropping of the class by multiple students.

We discuss the strengths and limitations of this new measure of student participation. Automatic recording of class participation frees up faculty time, which can be used to increase the quality of instruction. Low participation scores early in the course can help identify students at risk. Finally, we make recommendations to record attentiveness even more accurately.

Keywords: participation, attendance, attentiveness, distraction, student performance

1. INTRODUCTION

Student class participation has long been a subject of research. Before the advent of Distance Education (DE), participation was first measured in terms of coming to class (attendance), followed by the influence of different measures to increase attention while in class (hand raising, response cards, clickers). Ignoring previous DE forms like correspondence courses, the appearance of the Internet provided opportunities to offer asynchronous, usually text-based, courses as alternatives for face-to-face (F2F) classes. Measures of attendance then focused on time spent on the course site, clicks, and pages visited. Participation shifted to making meaningful contributions in email conversations and on discussion boards.

Overall, research showed that active participation in class improved subjective and objective student performance. Students perceived that they did better in class, and objective criteria like Grade Point Average (GPA) and scores on final exams confirmed this (Duncan, Kenworthy, Mcnamara, & Kenworthy, 2012).

As networks have improved in bandwidth, stability, and accessibility, the distinction between DE classes and F2F classes is starting to blur. Our regional university in the SouthWest now offers online courses (asynchronous), blended courses (part asynchronous, part F2F), interactive videoconferencing (ITV) from multiple campus locations, and virtual class meetings (VCM) as distance learning course types (Northeastern State University, 2019). Moreover, videoconferencing tools with screen sharing offer superior presentation compared with traditional blackboards, whiteboards, overhead projectors, and even smartboards. Using these tools both for F2F and DE courses is now a realistic option. Offering both options in the same course may increase attendance for students who miss class for employment reasons (Lukkarinen, Koivukangas, & Seppälä, 2016; Paisey & Paisey, 2004), while accommodating the majority who prefer lectures over web-based lecture technologies (Gysbers, Johnston, Hancock, & Denyer, 2011).

This paper presents a comparison of two Computer Science classes we used a video conferencing and collaboration tool, Zoom (Zoom Video Communications, Inc., 2019), to communicate with the students. Data available in the Pro Version are used to objectively measure student participation as the product of attendance (coming to class) and attentiveness (paying attention when in class). Levels of participation are related to performance in the class as measured by the score on the final exam, and differences in results for the two classes are discussed. To the best of our knowledge, this is the first time that coming to class (attendance) and paying attention (attentiveness) are combined to a single measure. It is also one of the few studies where participation is objectively measured only, without interpretation by the researchers.

2. LITERATURE REVIEW

Participation in class is a combination of coming to class and paying attention once there. Mere attendance may not matter until too much class time is missed (Durden & Ellis, 1995), but is a better predictor than SAT, high school GPA, study habits, study skills (Credé, Roch, & Kieszczynka, 2010), self-financing, and hours worked (Devadoss & Foltz, 1996). The research literature also supports that class attendance improves student performance (Romer, 1993; Coldwell, Craig, Paterson, & Mustard, 2008; Landin & Pérez, 2015; Teixeira, 2016; Yakovlev & Kinney, 2008; Landin & Pérez, 2015).

Once in class, being active matters. Beaudoin (2002) found that mean course grades were higher for learners who are actively involved in online discourse than for learners who just do the work. Participation is important both in synchronous and asynchronous conditions (Duncan et al., 2012). Multitasking with technology negatively affects participation and student performance, subjectively (Junco & Cotten, 2011) and objectively (Junco & Cotten, 2012). Typical non-class related multitasking includes use of instant messaging (IM) , FaceBook (Kirschner & Karpinski, 2010), and texting on cell phones . This is complicated by the use of some of these technologies for class purposes (Kraushaar & Novak, 2010). Using Facebook for class may have a positive effect, while using it for socializing may be negative (Junco, 2012b). Overall, using social media for class purposes may not be effective (Lau, 2017).

Meta-analysis show that student performance tends to be slightly better in DE courses (Allen et al., 2004) or positives cancel out negatives (Bernard et al., 2004), but this may be due to additional tasks for the students. When the task load is identical, for local and distant students in a videoconferencing setting, student performance is the same (MacLaughlin, Supernaw, & Howard, 2004). Interaction may be essential: DE with collaborative discussions is more effective than independent study only (Lou, Bernard, & Abrami, 2006).

Class Participation

Class participation is treated as the independent variable in the research. The definition of the term has developed over time. Before the introduction of the Internet in education, participation could mean use of response cards and hand-raising (Christle & Schuster, 2003; Gardner, Heward, & Grossi, 1994; Narayan, Heward, Gardner, Courson, & Omness, 1990). Once computers entered the classroom, participation might be measured by using tools like clickers (Stowell & Nelson, 2007). In the early days of DE, when most classes were conducted asynchronously, participation was typically measured with pages visited, tools used, messages accessed, discussions posted, and email contacts (Coldwell et al., 2008; Douglas & Alemanne, 2007; Romero, López, Luna, & Ventura, 2013).

Novel tools are now sometimes used to measure participation. Kassarnig, Bjerre-Nielsen, Mones, Lehmann, & Lassen (2017) used location and Bluetooth data from cell phones to measure attendance, and Kraushaar & Novak (2010) used spyware installed on students' laptops to check browsing and application use. Unfortunately, these tools may be good for research but not necessarily for day-to-day teaching.

Finally, a significant number of studies rely on self-report by students (Junco & Cotten, 2011), including self-report of GPA and hours spent studying (Kirschner & Karpinski, 2010).

Student Performance
On the other side of the relationship, student performance is used as the dependent variable. The most frequently used objective measures of student performance are items like course grades (Beaudoin, 2002; Durden & Ellis, 1995; Kassarnig et al., 2017; Teixeira, 2016), term GPA (Wang, Harari, Hao, Zhou, & Campbell, 2015), cumulative GPA (Lau, 2017), self-reported GPA (Kirschner & Karpinski, 2010), GPA obtained from registrars (Junco, 2012b) ,course credits (Giunchiglia, Zeni, Gobbi, Bignotti, & Bison, 2018) , scores on final exams (Duncan et al., 2012; Lukkarinen et al., 2016) and finishing the course (Coldwell et al., 2008; Junco, 2012a). Occasionally, pre-tests and post-tests (Omar, Bhutta, & Kalulu, 2009), student ranking (Felisoni & Godoi, 2018) or multi-item scales are used (Yu, Tian, Vogel, & Chi-Wai Kwok, 2010).

Multitasking
Using computer lab desktops or personal laptops does present new problems. Students often alternate between class-related and non-class-related computer use (Fried, 2008; Grace-Martin & Gay, 2001; Hembrooke & Gay, 2003).

Like class participation, this multitasking has evolved with the technology of the day. When laptops entered the classroom, instant messaging and web browsing were major distractions (Fox, Rosen, & Crawford, 2009; Hembrooke & Gay, 2003). Later, Facebook became a major distractor (Kirschner & Karpinski, 2010). Now, mobile phones provide yet another source of distraction (Chen & Yan, 2016; Harman & Sato, 2011). The negative effect of using cellphones is especially high when it takes place in class (Felisoni & Godoi, 2018), and lower performing students are especially at risk (Beland & Murphy, 2016; Chiang & Sumell, 2019). Beland and Murphy (2016) also found significant improvement in high stakes exam scores after mobile phones were banned.

Students do not necessarily recognize the negative effect. In a study of Malaysian university students, respondents felt that they performed better as Facebook usage increased (Ainin, Naqshbandi, Moghavvemi, & Jaafar, 2015).

The general research consensus holds that multitasking does have a negative effect on student performance (Bellur, Nowak, & Hull, 2015; Burak, 2012; Junco & Cotten, 2012; Kraushaar & Novak, 2010; MacLaughlin et al., 2004), although the causality has not yet been established (van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015). Controlled experiments show that actual performance may be the same, but the time to achieve it is longer (Bowman, Levine, Waite, & Gendron, 2010; Rubinstein, Meyer, & Evans, 2001). While some studies fail to demonstrate differences between performance of cognitive tasks with and without distraction, they do show decreased efficiency of information processing (End, Worthman, Mathews, & Wetterau, 2010) and increased memory errors (Rubinstein et al., 2001).

Use of Videoconferencing Software
Recorded lectures and posting notes online only may not meet students' needs (Gysbers et al., 2011). All modern Learning Management Systems (LMS) include some form of videoconferencing to enable virtual class meetings. Moodle has a Videoconference Edition (Moodle, Inc., 2019). Blackboard offers the Blackboard Collaborate module (BlackBoard Inc, 2019). Canvas includes the Conferences tool (Canvas LMS Community, 2019). Each have their strengths and weaknesses, and those will not be addressed here.

In addition to discussions via video conferencing, Zoom meeting features include presentation and collaboration features. Pure presentation can be done with desktop sharing, application sharing, whiteboards, slideshows, and sharing of online videos. Collaboration features like Instant Messaging, annotation and drawing tools, and remote desktop control transform the shared view into two-way communication between instructor and students (SJSU, 2018).

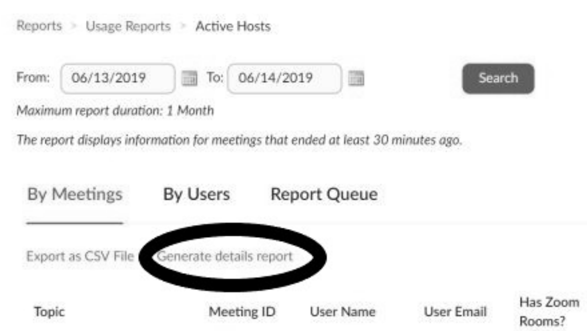

Figure 12- Details Report

Zoom comes in different versions. The free version is limited to 40-minute sessions and is not suitable for teaching full class sessions. Zoom for Education allows each host to teach full class sessions but has limited administrative tools for faculty. The Zoom Pro version is relatively inexpensive and offers extra administrative controls and reports. Join time, leave time, student name, and attentiveness score can all be found in the Details report (Figure 12).

3.METHODOLOGY

This research project involves using data automatically recorded by Zoom Pro. We analyzed data for two classes in the Mathematics and Computer Science department taught by the primary author. The first course, CS2014 or Computer Science I, is the introductory programming course with C++. The course consists of three lecture hours and one lab hour each week. Twenty-five students started the class, and 20 students took the final exam. The second course, CS3343 or Operating Systems, consists of three lecture hours only. Twenty-five students started the class, and 23 took the final exam. Both classes were taught as F2F classes in the same computer lab, and students were not allowed to participate remotely by college policy.

In the lecture sessions, students viewed the shared desktop of the instructor. All applications, whether PowerPoint, system utilities, virtual machines, or the C++ compiler, were used from the instructor's desktop. The syllabus instructed students to maximize the Zoom window, and to use pen and paper for any note taking. All lectures were automatically recorded and generally available after two hours.

In both classes, a variety of Zoom features were used to encourage or force students to be active participants. Students could pose anonymous questions on the shared desktop using the annotation and drawing tools. They could use the chat box for less immediate questions and comments. Voice communications were hardly ever used by students. A grid with names was used to respond to questions to the whole class (Figure 13). Individual students would take over control of keyboard and mouse of the instructor to finish or edit program code. This could be done as volunteers, or as called on by the instructor.

Distraction from the class was also actively discouraged. Students were required to keep their desktop camera on and trained on their faces. The stated goal was increasing the feeling of belonging to the group (class), but it also allowed the instructor to call on students who appeared to be less than attentive. Some students trying to take the class from another location, or even from a car while driving, were identified and either told to leave the meeting or removed from the session by the instructor. Cell phone use was prohibited, and students could only answer calls after leaving the classroom. Finally, no interactive desktop sharing was used where students – not the instructor - shared their desktop. Having students share their work increases diversity of solutions but is somewhat time-consuming and depends on all other computers having software correctly installed. A fortunate side-effect of limited sharing is the accurate recording of focus of students' desktops.

In your own words, define concurrency

Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name
Student name	Student name	Student name

Figure 13-answering grid

Grades on the final exam were used as measures of student performance. The final exam was comprehensive and covered the whole course. For the CS2014 programming class, this is a natural choice. Declaration of variables is necessary for using loops, and repetition structures are needed for reading and writing files. Each skill builds on what was learned previously. The choice for a comprehensive final in the CS3343 Operating Systems class is more a philosophical one. Formative assessments like programming assignments and intermediate tests help identify where students need more help and instruction as the course continues, and summative assessments like course projects and final exams serve to evaluate how well student outcomes have been achieved. In each course, several intermediate tests were used. For each subsequent test (including the final), 50% of questions came from "old" material and the remainder from material covered since the last test. This allowed for checking if previously missed concepts were now understood.

For each final exam, students had a review session where they could ask questions. The final exams in both courses were in multiple choice (MC) format.

Zoom Statistics
Zoom Pro allows generation of comprehensive meeting reports in Excel format. Data include topic, join time, leave time, and the "attentiveness score." Attentiveness in this context is defined as the percent of time that the shared Zoom window is in focus. If a student is logged in but works with another application, the time does not contribute to attentiveness. If students are disconnected during class and reconnect, each part will have its own attentiveness score. It is important to note that attentiveness is recorded for each individual student, whereas other software may only report "engagement" for the group (Adobe.com, 2019)

Students were required to log in for each meeting. Many students use inconsistent login names, so the name used for the BlackBoard gradebook was looked up in an alias table. Students also tend to log in before the class starts and may stay until after the end of class. During class, they may occasionally be disconnected and need to reconnect. The exact time of participation was calculated in new columns. We provide the formulas in Appendix A, and a template with all formulas is available at https://1drv.ms/x/s!AnmVh-GZtTJyv4UyDwd7xAK0EDw7hg?e=I2CWsX
To protect student privacy, we replaced student names with random numbers between 1111 and 9999.

4. SAMPLE AND DATA COLLECTION

Both classes started with 25 students. As usual in CS, the majority of students were male (CS2014: 22 males, 3 females; CS3343: 20 males, 5 females). Most students were traditional full-time students in their late teens and early twenties (CS2014: 2 non-traditional students; CS3343: 1 non-traditional student).

Class attendance and attentiveness data were automatically recorded by Zoom, since students were required to log in to the class sessions. Participation scores were posted on the Blackboard gradebook every two weeks, and students who scored low on participation early in the course received an email with separate data for attendance and attentiveness to explain why their scores were low. Since we measured the influence of conditions in for each student in one course only, we used the final exam in the course to measure performance. The final MC exam was posted on BB and scores automatically calculated. Questions and answers were reviewed based on less than 50% correct answers, and no questions were found to be incorrectly stated.

5.ANALYSIS

Since both Zoom and Blackboard gradebook were already in Excel format, we used the Excel Analysis Toolpak to perform the linear regression. All absences received a participation score of zero as no time was spent in class. Absences were not corrected for excused absences, such as attendance of events sanctioned by Academic Affairs. Students who did not finish the class and did not take the final exam were included with a zero score for the final. Statistics for both courses are listed in Appendix B.

It is interesting to note that none of the students got a perfect 100% participation score (maximum scores of 98.4% and 93.6%). This truly is an effect of attendance alone, since attentiveness is only recorded when the desktop is shared, and the instructor did not start sharing until the class started.

Linear regression showed a statistically significant relationship between participation and grade on the final exam for CS3343 ($p = 0.01$) but not for CS2014 ($p = 0.25$). One explanation of the difference may lie with the type of the class. CS2014 is a skills class, and CS3343 is a concepts class. Concepts classes predominantly use a lecture format, and skills classes use more of a lab environment with individual instruction (Sinclaire, Simon, Campbell, & Brown, 2011). Indeed, the CS2014 class included a one-hour lab each week. The hands-on component may have superseded the effect of lecture participation.

The influence of hands-on work in the labs can also be seen when comparing lab attendance and final grades. During the lab, students were logged in to a separate Zoom session to record attendance, but no desktops were shared and therefore attentiveness was not relevant. We found a significant relationship between lab attendance (not participation) and score on the final exam ($p = 1.24E-8$). This is consistent with the findings of (Barrington & Johnson, 2006).

Another explanation of the absence of a relationship in CS2014 may lie with late withdrawals. Students who withdraw before week 12 are removed from the course management system, but some students need to stay in a class for Financial Aid reasons and drop a course shortly before the final exam. They would still be represented in the data. Three students in CS2014 struggled with significant health events but tried to finish the class right up to the final exam, when their position was hopeless. Where CS3343 only had 2/25 students not taking the final exam, CS2014 had 5/25 or 20% dropping the final. Analyzing the data without the five non-final takers still did not show any statistical significance ($p = 0.65$).

Maybe due to financial aid and health reasons, the average participation score of non-finishers of 87.9% is higher than the class as a whole with72.9% Furthermore, students in the front of the class were extremely active in volunteering for taking over control, which may have allowed students further back in the class to "log in, and tune out." They may have finished the course, but with lower grades. Seating location does affect student performance, whether through random assignment (Benedict & Hoag, 2004) or through students being forced forward when their preferred seats are not available (Perkins & Wieman, 2004). Since data had to be anonymized before analysis, and seating location was not included, this will have to remain an issue for future research.

6. CONCLUSIONS AND RECOMMENDATION

Participation in class, as a product of attendance and attentiveness, may be a valid objective measure to predict student performance. Since it can be monitored as semesters progress, it can also be used to identify students at risk of failing and underperforming. This is especially significant, because the data can be recorded automatically in Zoom and analyzed with minimal effort in Excel.

This does not mean that the combination of attendance and attentiveness is a perfect measure of participation. Time of entering and leaving the session is a perfect measure of attendance, but computer focus on the application is not a perfect measure of attentiveness. It is still possible to log in, keep the application in focus, and play on a cellphone – or sleep. We can consider using screen captures of the answer grids in the lecture recordings to monitor and measure actual responding. Additional attention-focusing tools like sending code snippets or answers through the chat box, which records name of respondents so they can be counted, should also be considered. Individual students can also be called to attention based on signs of disinterest on the video images of their webcams. All these measures take time, and one of the major benefits of automating recording attendance and attention is freeing up faculty from the chore of attendance recording.

The type of class may matter. Concept classes may benefit more because hands-on work in skills classes offers additional learning opportunities. The interactive tools in skills classes are more limited to single students. Taking over control of mouse and keyboard only involves a single student but using chat boxes and grids with answer boxes for all students forces the whole class to pay attention.

An area of concern may be student acceptance of what could be construed as an intrusive technology. The use of Zoom monitoring should be disclosed, preferably in writing in the syllabus. We did this, and there were no complaints interpersonally or in the course evaluations. Instructors should take care not to open the shared desktop before and after class, since focus of the students' computers would be monitored then too. If students are given a choice between attending locally and remotely in the same class session, it must be made clear that students cannot attend using cell phones or tablets. The interaction requires the use of full-fledged keyboards and mice. Use of wireless connections for remote students can result in poor video and audio quality, as well as the need to reconnect.

The positive results of this study warrant repetition and refinement in other CS courses and in other subject areas such as humanities, social sciences, and business in future semesters. Further opportunities for research include counting responses in the chat box or onscreen, monitoring seating and comparing the results of skills classes with and without associated labs.

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Appendix A: Generating Data

A simulated details report is shown below. The column "Name (Original Name)" holds the student name as provided during login. The column "User Email" holds the student email as provided during login. Students often provide inconsistent login information, but a simple table with variations of the name can be used to look up the name as used in the gradebook.

Topic	Meeting ID	User Name	User Email	Has Zoom Rooms?	Creation Time	Start Time	End Time	Duration (Minutes)	Participants	Name (Original Name)	User Email	Join Time	Leave Time	Duration (Minutes)	Attentiveness Score
CS2014 CS1	213-885-828	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	118	20	(student name)	(student email)	3/4/2019 11:54	3/4/2019 13:50	117	53.36%
CS2014 CS1	213-885-828	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	118	20	(student name)	(student email)	3/4/2019 12:44	3/4/2019 13:50	67	84.97%
CS2014 CS1	213-885-828	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	118	20	(student name)	(student email)	3/4/2019 12:50	3/4/2019 13:50	60	100.00%
CS2014 CS1	213-885-828	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	118	20	(student name)	(student email)	3/4/2019 12:51	3/4/2019 13:50	60	98.56%
CS2014 CS1	213-885-828	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	118	20	(student name)	(student email)	3/4/2019 12:51	3/4/2019 13:50	59	30.34%
CS3343 Operating Systems	843-765-396	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	91	24	(student name)	(student email)	3/5/2019 9:19	3/5/2019 10:46	88	100.00%
CS3343 Operating Systems	843-765-396	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	91	24	(student name)	(student email)	3/5/2019 9:20	3/5/2019 10:46	87	95.06%
CS3343 Operating Systems	843-765-396	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	91	24	(student name)	(student email)	3/5/2019 9:21	3/5/2019 10:46	85	100.00%
CS3343 Operating Systems	843-765-396	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	91	24	(student name)	(student email)	3/5/2019 9:21	3/5/2019 10:46	85	100.00%
CS3343 Operating Systems	843-765-396	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	91	24	(student name)	(student email)	3/5/2019 9:26	3/5/2019 10:46	81	100.00%
CS2014 CS1 lab	167-747-341	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	59	18	(student name)	(student email)	3/6/2019 13:53	3/6/2019 14:50	58	23.83%
CS2014 CS1 lab	167-747-341	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	59	18	(student name)	(student email)	3/6/2019 13:53	3/6/2019 14:50	57	1.33%
CS2014 CS1 lab	167-747-341	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	59	18	(student name)	(student email)	3/6/2019 13:53	3/6/2019 14:50	58	15.67%
CS2014 CS1 lab	167-747-341	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	59	18	(student name)	(student email)	3/6/2019 13:53	3/6/2019 14:51	58	2.16%
CS2014 CS1 lab	167-747-341	(instructor name)	(instructor email)	No	(not relevant)	(first to enter)	(last to leave)	59	18	(student name)	(student email)	3/6/2019 13:53	3/6/2019 14:51	58	17.56%

Join Time and Leave Time for each entry are recorded in date + time format.

- Date can be extracted with the formula =INT([@[Join Time]])
- joined can be extracted with the formula =MOD([@[Join Time]],1)
- left can be extracted with the formula =MOD([@[Leave Time]],1)

Start and end times for the class can be looked up from a small table (named "classes") as follows:

- class_starts with the formula =VLOOKUP([@Topic], classes,2, FALSE)
- class_ends with the formula =VLOOKUP([@Topic], classes, 3, FALSE)

To accommodate for coming early, coming late, leaving early, and leaving late, we used the MAX and MIN formulas:

- start with the formula =MAX([@joined],[@[class_starts]])
- stop with the formula =MIN([@left],[@[class_ends]])

Next, the "real time" in class was calculated as the difference and percent in class as the fraction:

- real_time =[@stop]-[@start]
- percent_in_class =[@[real time]]/([@[class_ends]]-[@[class_starts]])

Attendance and attentiveness were multiplied and converted to percentages with two decimals:

- participation =ROUND([@[percent_in_class]]*[@attentiveness],4).

In the gradebook, participation scores were summed in case students were disconnected during class:

- session_participation=IFERROR(SUMIFS(ZoomData[participation], ZoomData[studentName],[@[full_name]],ZoomData[Topic],"CS2014_CS1",ZoomData[date],F$1),0)

Appendix B: Statistical Output

CS3343 – Operating Systems

participation		*final*	
Mean	76.2%	Mean	157.6
Standard Error	3.2%	Standard Error	10.8
Median	81.2%	Median	176
Mode	#N/A	Mode	204
Standard Deviation	16.2%	Standard Deviation	53.8
Sample Variance	2.6%	Sample Variance	2890.7
Kurtosis	1.69925609	Kurtosis	4.7
Skewness	-1.42638148	Skewness	-2.2
Range	61.2%	Range	204
Minimum	32.4%	Minimum	0
Maximum	93.6%	Maximum	204
Sum	1905.2%	Sum	3940
Count	25	Count	25

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.502818411
R Square	0.252826354
Adjusted R Square	0.220340543
Standard Error	47.47352528
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	17540.08114	17540.08114	7.782670302	0.010412384
Residual	23	51835.91886	2253.735602		
Total	24	69376			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	30.42582657	46.56460768	0.653410994	0.519970696	-65.90040348	126.7520566
participation	166.8806288	59.81933918	2.78974377	0.010412384	43.13489756	290.6263601

CS2014 – Computer Science I

participation		*final*	
Mean	72.9%	Mean	108.32
Standard Error	4.8%	Standard Error	12.45775796
Median	84.3%	Median	124
Mode	#N/A	Mode	0
Standard Deviation	23.8%	Standard Deviation	62.28878979
Sample Variance	5.7%	Sample Variance	3879.893333
Kurtosis	0.89846521	Kurtosis	-0.432090221
Skewness	-1.2805363	Skewness	-0.803775468
Range	90.4%	Range	196
Minimum	8.0%	Minimum	0
Maximum	98.4%	Maximum	196
Sum	1823.2%	Sum	2708
Count	25	Count	25

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.238435249
R Square	0.056851368
Adjusted R Square	0.015844906
Standard Error	61.79333936
Observations	25

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5293.85386	5293.85386	1.386400216	0.251054931
Residual	23	87823.58614	3818.416789		
Total	24	93117.44			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	153.8042887	40.55812226	3.792194514	0.000941171	69.90342045	237.705157
participation	-62.3679229	52.96841434	-1.177454974	0.251054931	-171.9414364	47.2055905