Micro-Credentialing with Fuzzy Content Matching: An Educational Data-Mining Approach

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MICRO-CREDENTIALING WITH FUZZY CONTENT MATCHING: AN EDUCATIONAL DATA-MINING APPROACH

by

PAUL AMORUSO
B.S. University of Central Florida, 2021

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
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Major Professor: Ronald F. DeMara
ABSTRACT

There is a growing need to assess and issue micro-credentials within STEM curricula. Although one approach is to insert a free-standing academic activity into the students learning and degree path, herein the development and mechanism of an alternative approach rooted in leveraging responses on digitized quiz-based assessments is developed. An online assessment and remediation protocol with accompanying Python-based toolset was developed to engage undergraduate tutors who identify and fill knowledge gaps of at-risk learners. Digitized assessments, personalized tutoring, and automated micro-credentialing scripts for Canvas LMS are used to issue skill-specific badges which motivate the learner incrementally, while increasing self-efficacy. This consisted of building upon the available Canvas LMS application programming interface to design an algorithm that takes the given Canvas LMS data to develop the automation of dispersing badges. In addition, a user centric interface was prototyped and implemented to garner high user acceptance. As well as pioneering the potential steps to efficiently migrating the classical quizzes to New Quizzes format and investigating potential steps to provide personalized YouTube video recommendations to students, based on assessment performance. Moreover, foundational research, operational objectives, and prototyping a user interface for instructor-facing micro-credentialing was established through the work represented in this document. The approach developed is shown to provide a fine-grained analysis that credentials students understanding of material from a semester-wide perspective using a scalable automation approach evaluated within the Canvas LMS.
ACKNOWLEDGMENTS

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CHAPTER ONE: INTRODUCTION

Need for Micro-Credentials

The need for Micro-Credentialing comes from higher-education instructors, desiring to provide students with a way to advertise their exceptional knowledge, and identify what topics other students are lacking. Utilization of the digital micro-credentials is in response to the current domination of GPA and letter grades that offer very little clarity on representation of evidence-based student competency in particular subject matters. Micro-credentials provide students, instructors, and committees with digital badges that are portable and evidence-based to evaluate learning [1]. There have been many ways Micro-credentialling has been attempted, such as tracking student activity on learning resources provided by an instructor and making a matrix of assessments route, which was taken in the approach. It was concluded that if new methodology was attempted where a matrix of quiz questions is developed and associate those questions with labels that identify the knowledge needed to answer them. Then it may be possible to make a way to keep track of each student’s performance on each question among multiple assessments to make a threshold that should say whether a student deserves a badge. For example, students can pass a course, but that does not mean that they are proficient in every topic that is taught. Additionally, it may be hard to identify what skills in a technical course a student is struggling with. The matrix will allow instructors to easily tag skills to each question. Then the program uses the statistics on the given quiz to calculate the students’ performance on a skill-by-skill basis, after the students take their digitalized assessments. While also providing the instructors with an overall student performance for each achievable skill. The importance of a digital badge stems from its importance
to not only provide a reward to the students, but to allow for the student’s skills to be identifiable to those that require them. For instance, badges show usefulness in various fields such as being utilized in the military to show that a person has a set of credentials that can be identified speedily to use in a certain scenario [2].

One of the main purposes of the utilization of micro-credentialling is for its integral role in the Building-the-Capacity Ecosystem (BC-Eco) in Figure 3. Based on the prominent use of digitalized assessments among the College of Engineering and Computer Science (CECS) and the College of Sciences (COS) at the University of Central Florida, the BC-Eco project was initiated to try to ensure student learning. The system was intended to extend the testing-and-tutoring model to make a sustainable ecosystem with the goal of increasing enrollment capacity and graduation rates among various students learning types. There are three levels of the ecosystem, with the generation of digital micro-credentials from student assessment results as one of the levels.

UCF demonstrated with multiple studies, that by implementing digital assessments properly in STEM courses, the enabling of significant learning gains among a broad range of learners is achievable [3]. Therefore, building on that knowledge of properly implementing digital courses, the continuance of wanting to ensure to the highest quality, so that no students are lacking in important knowledge was aimed for. The first implementation of the research was tested in EEL 3801 Computer Organization Spring 2022 on 70 students. Each student’s performance was analyzed after each assessment and was tagged with a badge if worthy, along with providing the students with specialized tutors that would help outside of class and provide rebuttal sessions for points back on the assessments. After researching throughout the semester, it was found that 36
students received at least one badge, meaning that about half of the students were qualified enough to say they were proficient enough to claim proficiency in a particular part of the course material. Additionally, the development of digital badges for each skill attainable in the course and provided them with a link to the image (hosted on cal.ucf.edu), along with instructions on how to add it as an award on their LinkedIn account. The University of Central Florida has demonstrated via multiple studies how properly digitized assessments are not only viable within STEM courses but can also help to enable significant learning gains among diverse learners by reallocating human resources for meeting personally with students [3].

The development and automatic distribution of micro-credentials allow the opportunity for an instructor to target and remediate selected skills. Part of the future work consists of automatically recommending remediation-based videos to support the filling of knowledge gaps. There have been many attempts to help students learn the material they lack knowledge in. Thus, building on the idea of micro-credentialling scripts to harvest assessment questions, by matching informational videos on YouTube to questions on the assessment, there is potential to prescribe videos to students based on what questions they got wrong. In starting the research topic, after extensive investigation, it was found that the best initial method to get the project off the ground was to use TheFuzz algorithm. Using the Levenshtein distance to calculate the differences joining sequences [4]. The study is built upon the micro-credentialling aspect, to enhance student understanding on information tailored to the student. Through, tracking student performance on more niche questions within the assessments, it is possible to implement a particular algorithm to
identify key words or phrases from the missed questions, to identify video clips that cover such material.

**Credentials by Data-Mining**

The dependency on the data provided by the LMS was a key component in tagging skills to questions within the digital quiz-based assessments and to award credentials to students. The manner in how the data is collected along with what type of data was available served key to the process. Multiple methodologies were contemplated to pick the most efficient and practical way of collecting the data. Options that were reviewed are quiz statistics documentation generated by canvas via the instructor, and API requests. The main hurdle that was encountered when trying to collect dependent data was with Canvas permission on accounts for security reasons. If the route of having the instructor extract data themselves, it led to relatively inconvenient processes for the instructor and limited the kind of data receivable. One the other hand, utilizing API’s requests provided an open field in types of data providable, it would require user authentication to collect. The tradeoff analysis led to the conclusion that prioritizing data was most important and worth the application’s hurdle to overcome authentication. In picking the API route to collect data, Canvas documentation was reviewed throughout the development of the applications seen in this document. Canvas LMS allows REST API request where “all API access is over HTTPS, against your normal Canvas domain” is stated Canvas LMS documentation [5]. After an API request is made, the output is in JSON format for all data which is traversed to collect only necessary information and discarding any fluff that does not facilitate in analyzing student potential micro-
credentials. REST APIs hear to HTTP methods, such as the GET operations to obtain existing source [6] that was used within the python scripts MatrixMaker and SkillAssigner.

Integration Feasability with Canvas LMS

In part with the EIN6258 Human-Computer Interaction course, a redesigned user interface for the Python script outputs were integrated with the micro-credentialing digital toolset. The idea is so that future users, such as instructors may use a simple user-friendly application to track student skills and badges across a semester long course. The issue with the initial design, was the technical understanding and time it took for someone to run the MatrixMaker and SkillAssigner. The initial way of running the scripts was by modifying the source code to get the questions and statistics from the assessment and display in a CSV file. Therefore, focusing on what the user prefers, there will be options for the user to display on the most important data in the manner they prefer.

The idea that the abstract aims to highlight, is the importance of presenting data to instructors and or other individuals in charge of student performance in a user-friendly customizable manner. After developing a Python-based toolset to engage undergraduate tutors with an accompanying online assessment and remediation protocol so that they may identify and fill knowledge gaps of at-risk learners, a lookback at the work was performed to see if the toolset can be redesigned to make it more usable than it already is. It was studied that the field of human-computer interaction is concentrated with the steps of designing, evaluating, and implementing an interactive system that humans utilize. Therefore, the topics importance is due to the aim to enhance the interface so that users of the Python-based toolset that was made in the previous semester is easy to use for
most humans and have high user-acceptance so that more instructors are willing to adopt it in their courses. Overall, good user-interfaces have an important impact on someone’s ability to accomplish the task such as micro-credentialing.

Presented is a user interface the builds upon previous work that consists of a quiz-based digital assessment and remediation protocol with an accompanying Python-based toolset was developed to engage undergraduate tutors who identify and fill knowledge gaps of at-risk learners. The utilization of digitized assessments, and automated micro-credentialing scripts for Canvas LMS to output skill-specific badges which motivate the learner incrementally, while increasing self-efficacy. The problem with the framework tools that existed prior was that they were not developed with user centricity in mind, making it require a large learning curve from users to operate. The user interface that was made requires no programming knowledge to run the applications that provide STEM instructors the ability to tag skills to assessment questions for credentialing students and getting assessment by assessment feedback on overall class performance. No matter which genre or tool, what sets it apart from similar products, is user-acceptance built upon effectiveness and usability. A survey was also performed to identify the opinions and level of acceptance from potentially ideal users viewing and interacting with the interface prototype.

Contributions and Organization of Thesis

In the established framework, an online assessment was developed along with a remediated protocol with a Python script to accompany it. The intent with this research was to provide a method of micro-credentialing via Fuzzy Content Matching, using an educational data-mining
approach via API requests. When online virtual education is done correctly, students may get adequately educated in the respective course by providing opportunities to underrepresented students. The work was in conjunction with enabling graduate along with undergraduate teaching and learning assistants trained to help with rebuttal sessions to provide students with necessary points and explain the answers. Micro-credentialing via the matrix tagging approach via the mining of key data from the Canvas LMS opened the door for achieving the discernment of badges via advantages offered by this approach, including:

a) **intrinsic tailoring of micro-credentialing**: developed design and blueprint for making a globally scaled skill analysis for micro-credentialing digitized quiz-based assessments,

b) **tagging explicit skills to distinctive questions**: using fine-grained analysis techniques to disperse badges required the organization and dissemination of instructor specified skills to tag individual questions,

c) **charting the integration feasibility within the Canvas LMS**: utilizing Canvas’s REST API, the micro-credentialing software along with other scripts developed in this thesis aimed to be seamlessly integrated within courses,

d) **prototyping and deploying a ready to use application**: there are various corporate companies aiming to solve the niche to provide instructors with the tools to micro-credential. Yet, the most common approach is seen using additional platforms with premium cost and time investment from the instructors and or course managers. The methodology seen in this document shows a minimal invasive approach via its integration with Canvas LMS and simple design that was reviewed by various instructors.
One of the most integral parts of the overall research came from the data provided from the quizzes within Canvas learning management system (LMS). With Canvas LMS pushing instructors to migrate the so-called Classic quizzes to New Quizzes, the dependency on how to support the new format is ever so important. Making the process of steps taken to establish the quizzes so that it is possible to collect data and provide the best method of testing students in the most efficient way provided within this document. Therefore, work has been in progress to assess and provide the steps needed to smoothly transition to new quiz format on Canvas LMS. In continuation with the personalization of digitalized assessments for optimization prior remediation, the maintenance and continuous updates should be done to the assessments. As mentioned via the Canvas LMS company, “New Quizzes is a new assessment engine built to meet the assessment needs in your classroom today and in the future” [7].

The thesis is organized as illustrated by Figure 1: Chapter 2 reviews related works in the field of micro-credentialing with the various methodologies researchers and companies aim to fill. Chapter 3 outlines the specifics of the foundation on which this research builds upon, beginning with an overview of the importance micro-credential has and proceeding to discuss details of the framework that was developed to assign credentials to students in the university, and proceeds to assess the impact and playbook that was developed with Dr. Ronald F. DeMara to help migrate the quizzes the Canvas LMS. The framework seen in Chapter 3 is then used to build upon for high user acceptance in implementation with emphasis with human computer interaction design in Chapter 4. Finally, Chapter 5 concludes the thesis by giving a technical summary, and outlining insights gained and future work in the field.
Chapter 1: Introduction

Need for Micro-Credentials

Credentials by Data mining

Integration Feasibility with Canvas LMS

Contributions/Organization

Chapter 2: Related Works

Coarse-Grained Approach

Completion-Based Micro-Credentialing

Skill-Specific Micro-Credentialing

Summary

Chapter 3: Personalizing Digitized Assessments Using an Automatic Micro-Credentialing Framework for Canvas LMS

Framework Tailoring for STEM Foundational Software In-Use Adoptions for New Quizzes Adaptations to the LMS Remediation Framework

Chapter 4: Instructor-Facing Micro-Credentialing User Interface: Foundational Research, Operational Objectives, And Prototype

Framework MatrixMaker SkillAssigner Evaluations & Results

Chapter 5: Conclusions

Technical Summary Scope and Limitations Future work

Figure 1: Outline of thesis. Preliminary versions of some of this work appeared as author in a publication within the 2022 OLC Accelerate 2022 Conference on Accelerating Online Learning Worldwide [8].
CHAPTER TWO: RELATED WORKS

Coarse-Grained Approach

In most K-12 and higher education schools the typical method to quantify student’s competency is based on letter grades. If universities are supposed to provide career dependent skills to their students, then how are grades or percentages the correct method of displaying these skills? In fact, major companies such as Google, prefer to onboard people that have received skill specific digital lessons with certificates over a GPA score. In addition, tech giants such as Google, Adobe, and Microsoft provide special IT certificate-based courses that are considered to be highly ranked within the industry [9]. This means that while higher education is supposed to provide their students with the skills and thinking process necessary for the workforce, large companies prefer online certificates over formal course work education. Leading to the conclusion that the universities for the most part are not providing the correct measure of competency. Understandably this lack of status the GPA holds, is due to its coarse-grained approach to measure student comprehension. President of Southern New Hampshire University, Paul LeBlanc states that employers can only infer what topics students have proficiency in, based on the given transcript, and that the employer “can make no trustworthy assessment” based on a simple transcript of letter grades [10]. Furthermore, universities seem to not trust grades delivered by other universities, since transfer students are often faced with reluctances from the new university to accept all credits. So, are certificate-based courses the best, since they are held with more respect compared to letter grades? The short answer is technically no, certificate-based courses are based on the foundation that completing a course or module is enough to award a certificate. Thus, students are awarded
certificates based on completion of a course or module rather than a realistic scenario where multiple skills are put to the test on a global scale. In all, skill certificates and course letter grades are generalized indicators that a student was shown a particular set of information and skills, rather than showing any specific skillsets a student was able to show significant competency with.

Completion-Based Micro-Credentialing Approach

Awarding badges or the process of micro-credentialing students are not new to higher education. More importantly various companies have aimed to provide solutions to fill the niche to provide badges to “validate competencies, drive engagement, improve completion, and increase enrollment” [11]. Companies such as Badgr, Accredible, and Credly dominate the market yet seem to skip over the key goals this paper aims to achieve.

Badgr grants instructors and course designers the ability to manage badge requirements in the courses and review privacy protected leader boards and other features such as learning pathways to motivate students through the course. Badgr provides a leaderboard that helps to track individual student performance and provide a gamified view of acquiring badges. Given the several key features the company provide in viewing, designing, and dispersing the badges, the system only allows in instructors to provide badges by either overall course grade or completion, module completeness, and or assignment performance or completeness [12]. In July 2018, Canvas LMS announced that they would use Badgr as their badging solution making it one of the commercial products that would later join the domain of being an academic product after its acquisition by Canvas is 2022 [13].
Accredible advertises the product with their three main features, that include the automation of badges and certificates, the ability for students to view badges natively within the Canvas LMS, and the use of single sign on (SSO) for automatic authorization [14]. Similar to the other products, Accredible is dependent on the instructor or course designer to use modules based on certain topics to quantify the student’s worthiness of credentials. The company states that they have worked closely with customers for easy integration with the LMS.

Credly by Pearson presents users with various solutions. They provide digital credentials to entice the engagement seen in classroom settings for example, provide the students with a visual token to display what they accomplished in the course. Going beyond the digital badges the company claims that their product allows the workforce to understand the skills employees may bring in a particular position, provide insights on positions in the future, and allow for a better understanding on what to recruit for. The software is installed on canvas as a LTI application and is available to a university wide or course specific solution. The Credly application is set up to award students with badges to discrete assignments or modules upon completion [15, 16]. Making the solution resembling both Badgr and Accredible.

Most products and services in the industry that are in the same or similar realm consists of having instructor’s user multiple websites/platforms and dependency on using modules to track student performance on a skill or topic that requires a badge. There are three main features that sets the user interface and experience presented in this paper apart from Badgr, Accredible, and Credly. Which is the minimal invasion to implement in a preexisting course, the ability to tag
multiple skills throughout the semester standard digital quiz-based assessments, and a simple interface that needs very little learning to operate.

**Skill-Specific Micro-Credentialing Program Approach**

There are various approaches to perform fine-grained analysis of student competency with a desire for a granular analysis on student outcomes from courses that are allow for detailed descriptions of the skills that obtained in a course. The SUNY Micro-Credentialing Task Force oversaw the examination of the methodology to implement micro-credentials in higher education at the State University of New York. The initiative uses SUNY course material in conjunction with workshops, traditional coursework, applied learning involvement, and certification training. SUNY micro-credentials were intended for current students, alumni, and those that aim to add new skills in their resume [17]. Their goal allows SUNY credentials obtainable to the masses, it requires the development of skill specific courses that are outside of the accredited program of study students must take. The Information Literacy Badges at Penn State employs 10 digital badges supported with Mozilla’s digital badge backpack to allow undergraduates the opportunity to receive badges to advertise themselves with [13, 18]. The methodology was to develop courses surrounded on the bases of skills. Each badge is made of a series of steps that the student must grind through. With each step relying on the instructor to specify content, and criteria that make up the badge. In addition, Penn State University Library information literacy digital badging initiative requires students to submit evidence for a badge, where a librarian or instructor is intended to review with the intention that the student will receive feedback on any steps needed to
acquire the badge [18]. The Badging Essential Skills for Transitions (B.E.S.T.) is a system derived from the University System of Maryland (USM) to introduce the process of dispersing badges to students. B.E.S.T is utilizing Credly as the badging medium for developing and disbursement of the digital badge. The USM institutions piloted the badges with selected set of students that must follow a set of criteria and rubrics to claim a badge. Yet, the system applied a breadth primary approach where multiple institutions were provided relatively generalized badges over specific badges. In addition, The Universities at Shady Grove accepted the greatest number of badges in 2018 of three badges to an entire institution to disperse to the students in specialized courses. The badges are consisting of broad skills such as in communication, critical thinking, and interculturalist thinking. This is a small step in the direction of dispersing badges, as they only have a handful of badges that a school can pull from [19]. The OpenBadges website is a tool developed by Mozilla to provide a place that instructors or anyone wanting to disperse badges can come to for making, managing, and dispersing badges to students or whomever completes a badge worthy task, so that they may add to their digital resume [13, 20]. OpenBadges are one the major corporate players aligned with the concept of the era of digital learning, with the importance to give liberty to the student to aim for goals to obtain and advertise badges. Digital educational badges allow the students to reflect on the skills obtained, while also providing a sense of tangible credits that can directly be utilized for future careers while fundamentally allowing students to grasp the importance of learning subjects [21]. Other attempts at implementing micro-credentials involve universities such as the University of Melbourne to develop a 12-month program to train employees for companies and provide digital badge certificates in a particular skillset. The
universities approach to use their educational resources for training busy professionals in the field is an innovative business plan for the university, however it is not necessarily catering to university’s own students that potentially work for the companies that are interested to have employees with the so called MicroCerts the offer [22].

**Summary**

While micro-credentialling is known broadly and been an active area of research, there has been quite a few methodologies of trying to achieve a similar goal as presented in this document. However, as seen in the technical investigation summaries above, there has been many weak points in obtaining the desired output. One of the main points that most appeared to follow, is the dependence on students completing skill specific assessments, or completing skill specific courses. The problem with such approaches is the potential time requirement inconvenient for both instructors to redevelop traditional core courses, and students who must interact with the changes on an already busy schedule. The taxonomy Figure 2 presents, related avenues in performing fine-grained analysis and the scope each partakes within upper education.
Figure 2: Summary of challenges and potential solutions relating to Certificates of Learners Efficacy.

As stated earlier, there are two main categories micro-credentials are implemented, there is the completion-based assessments, such as the Badgr, Accredible and Credly are known for, where students are mostly awarded based on the completion of a skill specific assessment or group of assessments. Then there is the skill specific program route that are in most cases specialized courses offered to university students or anyone willing to take courses centered in specific skills in often non-traditional sense. The two ways of gaging the students’ performance is sufficient, yet there are bases to argue that they may make developing and taking the course more cumbersome, in addition to focusing on a specific skill topic at a time, rather than realistic global scaled skill analysis. As seen, all the similar studies have a commonality, in that they strive to find ways to
improve the learning experience. Table 1 catalogs the various features for each of the major fine-grained analysis organizations and shows that the research presented trades the tagging of skills to assessments or modules for tagging of questions.

Table 1: Fielded Frameworks Comparison.

<table>
<thead>
<tr>
<th></th>
<th>Type</th>
<th>Supports Canvas LMS</th>
<th>Completion Based</th>
<th>Tags Skills to Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Badgr [12,13]</td>
<td>Academic</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Accredible [14]</td>
<td>Commercial</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Credly [15,16]</td>
<td>Commercial</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>MatrixMaker &amp;</td>
<td>Academic</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>SkillAssigner</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correspondingly, Table 2 lists some software frameworks that are available for issuing and managing academic badges. These platforms were evaluated by the project team based on the consideration of their extendibility, API design features, data robustness, and popularity. It is significant to note that the Open Badges development project is not a platform by itself [23]. In essence, while the badge categories themselves are open source in all cases, not every software platform issuing the badges is readily extendable. In fact, of the 24 IMS certified badge-issuing platforms [24] undergoing various uses today in academia, in many regards only Badgr is free and open-source code-based initiative.
Table 2: Representative frameworks for issuing and managing academic badges.

<table>
<thead>
<tr>
<th>Name</th>
<th>URL</th>
<th>Cost</th>
<th>Features</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accredible</td>
<td><a href="https://www.accredible.com">https://www.accredible.com</a></td>
<td>Free (up to 20 recipients)</td>
<td>-Design/create/deliver badges</td>
<td>[25]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Canvas integration</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>-Native Canvas support</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Free and open source</td>
<td></td>
</tr>
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<td>Openbadges.me</td>
<td><a href="https://www.openbadges.me">https://www.openbadges.me</a></td>
<td>Free (up to 50 badges)</td>
<td>-Multilingual badges</td>
<td>[27]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Advanced rules-based issuing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-Canvas integration</td>
<td></td>
</tr>
</tbody>
</table>

The NSF Python script-based framework analyzes student performance on a question-by-question basis. For each student and for each badging category, the software framework examines student responses to determine if student responses to those questions were correct up to the threshold set by the instructor. The goals seen in the related research loosely match the angle of direction the solution in this document presents. While the solutions that are presented in the related research work for their respective niche scenarios, the goal was to provide a very applicable methodology that can be applied to nearly any STEM course using online assessments. The hypothesis was that by successfully identifying student skillsets, it is possible to provide students with an opportunity to set themselves apart from others when getting into the workplace, and potentially pair students within courses that can benefit each other the best in skillset.
CHAPTER THREE: PERSONALIZING DIGITIZED ASSESSMENTS USING AN AUTOMATED MICRO-CREDENTIALING FRAMEWORK FOR CANVAS LMS

The Building-the-Capacity Ecosystem (BC-Eco) developed by the project leverages digitized assessments that automate micro-credentialing of student skills to facilitate personalized tutoring, peer-mentorship, and internships. The Services Provided are listed on the left-hand side of Figure 3. The foundational level, referred to as micro-credentialing, utilizes digitized assessment data that is capturable from 29 STEM courses having assessments that were already digitized in the UCF curriculum from 2014 to 2019.

Figure 3: Building-the-Capacity Ecosystem (BC-Eco) [8]

Starting at lower-left corner (★), students taking STEM courses follow along the gold-colored arrows as Student Mentees to Student Mentors to Interns. Students’ progress upwards through levels of Micro-Credentialing, Peer-Tutoring, and Industry Internships. Learning activities span Culturally Relevant Instruction within gateway courses, Underrepresented
Recruitment subsidized by tutoring stipends, and financially supplemented opportunities for Career Training. Based on the success of digitized assessments in the College of Engineering and Computer Science (CECS) and in the College of Sciences (COS) at UCF, their benefits to students, the multi-disciplinary BC-Eco Project has been initiated as shown Figure 3. One of the three levels of student-facing mechanisms is generating digital micro-credentials from digitized assessment results. This is automated by developing micro-credentialing Python programming language computer scripts via a one-time tagging step of the questions within the digitized assessments in STEM courses.

Successfully earning digital micro-credentials constitutes the first step for student participants by becoming a tutoring candidate. For example, a student may earn a digital micro-credential in a topic such as Finite Element Modeling or Human Computer Interface Design.

**Micro-Credentialing Framework**

Micro-credentialing is a subject of active research and offers more portability and flexibility to evaluate student skills beyond grades and test scores. In this NSF project, an open-source framework for awarding and managing badges is developed far beyond what already exists. Micro-credentials provide mechanisms for quantifying student skills, abilities, and knowledge beyond traditional grades and transcripts. In the context of this project, students are awarded through digital badges obtained through data mining of their digitized assessment data.

Micro-credentialing is an emerging means to authenticate an achievement, accomplishment, or even readiness to advance [1]. Micro-credentials are achievable to students in
the fraction of the time of traditional degrees, making the credentials collectable throughout higher education process for students and enabling institutions to target specific skills that are in demand [28]. It has been suggested that digital micro-credentials may increase equity and improve retention in higher education [29]. Students’ acceptance of the value of micro-credentialing is a key motivating factor for earning micro-credentials which in turn can increase motivation during learning [30]. The BC-Eco micro-credentialing process commences as students complete their assessments, via Python programming language scripts. Operationally, data mining and data-driven discovery approaches provide a bottom-up alternative to using contextual state information and interactive cues as in top-down reasoning approaches [31]. Specifically, the project reaches means to deliver and refine STEM micro-credentials through the annual cycle shown in Figure 3.

The inspiration for our Micro-credentialing process was based on the physical badges used by websites such as Stack Overflow, offering students the ability to share and display specific aspects of their achievements compared to the typical transcripts or grade-point averages. Moreover, micro-credentials can be used to represent student learning, to increase opportunities for students to achieve expertise through learning experiences spanning various contexts and to establish learner accomplishment more holistically [28,32]. For instance, since 2011, the Mozilla Foundation has provided open-source digital badges through the Open Badges Initiative (OBI) [28]. Moreover, micro-credentialing opportunities also offer new tangible incremental outcomes for HSI students’ resumes and LinkedIn profiles.
Tailoring Micro-Credentialing for STEM Assessments

In the first year of this four-year project, substantial progress towards a transportable micro-credentialing framework of the Building Capacity Ecosystem (BC-ECO) project was completed in accordance with the project plan. Activities completed include the following:

- Initiated identification of subject matter areas and expertise in selected content areas while training research assistants in specialties of educational data mining,
- Negotiated allocation of space for computer stations in tutoring room area,
- Refined plan and materials for solicitation of participants in the project,
- Programming language selection and database configuration for micro-credentialing software based on first-round targeted courses, and
- Requirements analysis/prototyping to develop micro-credentialing software framework.

Foundational Micro-Credentialing Software Currently In-use

For this type of data mining, the NSF project has developed a Python script-based framework which outputs a CSV file listing student performance on a question-by-question basis. The Python script was developed to meet the requirement specification by first traversing all the questions in a quiz to classify each question into a specific category, e.g., Theoretical skill or Applied skill. Next, for each student and for each badging category, the software framework examines student responses to determine if student responses to those questions were correct up
to the threshold set by the instructor. Thereby, the software identifies whether to award a badge in the specified category to each student.

Figure 4: Flowchart of micro-credentialing script execution created in this project as a transportable framework for Canvas LMS

Application Programming Interfaces (APIs) were utilized since they enable user-level applications to communicate seamlessly with each other. It is not practical to download the data manually from Canvas. Nonetheless, a faster and more efficient way is to automatically export data to the micro-credentialing application by using APIs. By sending an API request, it can be possible to automatically obtain the required information as well as alter data on Canvas [33].

The Micro-Credentialing Framework for Canvas requires data extraction. The Python programming language was utilized since this language comprises of libraries that makes it easier
to extract data and perform machine learning algorithms. First, the Script extracts the values of specific data fields residing within the Canvas Quiz data export format. Canvas has several APIs that help collect the information without downloading the data manually. Initially, we prototyped using free for teacher canvas website known as Canvas for Teachers. A sandbox course was created to start the implementation of the micro-credential software.

As shown in Figure 4, upon the receipt of API request, a JSON data file is generated by the Canvas LMS using the API call. This API retrieves information about the questions for that specific quiz, including the unique ID for each quiz. This is a vital step since it is required in a subsequent step to drill down to each question text string and response text string. Parsing of the JSON data is conducted since each micro-credential requires only a few specific fields from the entire dataset. The JSON data that is received is being converted to a DataFrame via Panda’s DataFrame library in Python. The DataFrame allows us to store data in a table-like structure that comprise of rows and columns for easy classification. The data that comprised of IDs and names of the students were in a list format. Thus, the Python script acquires the data while performing some field remapping to generate a CSV file each time the script is invoked. Later, capabilities will be added so that students can link their Micro-Credentials to the students LinkedIn pages, which can advance their internship/hiring connections with potential employers.

**Status and Conclusion**

Micro-Credentialling is intertwined with BC-ECO segment such as remediation, where students may consult with tutors to discuss their assessments. Each part of the BC-ECO aims to
help garner student learning, where the effects will be seen in the badges received by the students. The current phase of research in the project includes constructing a Python Dictionary data structure that will be used to evaluate student skills to issue micro-credentials within each course. The Python programming language scripts developed are available upon request [8].

**Adaptations to Support Migration to New Quizzes**

With the relative recent push from Canvas LMS to fully migrate from “classic quizzes” to “New Quizzes,” there has been a void in knowledge among educators in how this will affect the daily ins and outs of the LMS utilization or how to implement. These changes may be overlooked in simple Canvas LMS based courses taught, such as those with basic multiple choice or select all that apply questions. However, the implications caused by the recent changes on existing systems built upon “classic quizzes” are mostly unforeseen, till fully implemented in all possible courses. To guide the way and give warning to others, a relatively thorough examination and live testing implementation was performed to identify the challenges various STEM instructors will face. The guide seen here, is not a full list of all potential scenarios, however, was developed in mind to test as many reasonable scenarios imaginable and documented in a report called Canvas “New Quizzes” Primer.

Three commonly used scenarios were identified and reported with known solutions or workarounds. The process starts with migrating “classic quizzes” to the “new quiz” format. This migration leads to the first hurdle of having to remove all questions within question groups in the classic quiz prior to migration, or else the questions become non-editable. Furthermore, new
quizzes are different than the classic quizzes with the way that formula-based questions use different symbols to indicate answers to the questions. “Text” questions are also something new to consider with, as New Quizzes converts them to “Stimulus” which may cause viewing issues on the student side.

According to the Instructure community, who owns the Canvas LMS, the New Quizzes is a quiz engine that was developed with intentions to have features for the future that include a series of qualities and new item types, along with attempted improvements with workflow that were not seen in the Classic Quizzes [34]. The haste that New Quizzes brings, is that that the Classic Quizzes will not be supported forever, and that that some feature in Classic Quizzes will start get restricted eventually. Instructure’s reasoning for the switch, is the supposed benefits that GraphQL has over REST API. When new features are requested by the users, this can cause what is known as a “breaking change.” This is when new features make a new version of the API, making a tradeoff analysis by the organization to determine if the time and effort is necessary to update and release a new version. Thus, GraphQL yields only what is explicitly asked for, with the ability to add new data fields with exclusion of “breaking change” [35]. In addition, New and Classic quizzes are two different applications, and do not share a common database [36]. This means that REST APIs are things of the past for the organization, and that applications such as the ones developed to micro-credential, must adapt to GraphQL.

To convert quizzes to the new format the first step is to open the existing “Old Quiz” in Canvas. Next, click on the three dots menu icon on the upper right side of the quiz assessment window. Next, click the Migrate button. The rocket icon located to left of the Quiz listing becomes
displayed using a solid (shaded) icon as seen in Figure 5 from the *Canvas “New Quizzes” Primer* document.

![Diagram of Canvas interface with a shaded icon and menu options](image)

The rocket icon located to left of the Quiz listing becomes displayed using a solid (shaded) icon. Please refer to the following image:

![Diagram of Canvas interface with a shaded icon and menu options](image)

**Figure 5: Essential Migration Steps**

As mentioned earlier, the migration tool supports various question types. However, it is not possible to edit questions within question groups the originated in an “Old Quiz” once it becomes migrated to “New Quizzes.” For instance, any question groups of “Fill in Multiple Blanks” questions, can feasibly be migrated automatically sufficient to deliver the assessment in your course without manual editing. However, it will not be possible to edit the questions within those groups. This is because the migration tool translates the question group as a single unit that cannot be modified once in new quiz format.
Figure 6: Current Question Group Solution Guide

To accommodate formula-based questions, create a Fill in the Blank question and then use the "'" so called-backticks apostrophe symbol before and after the words to indicate where a student will fill in their answer. Specifically, the Classic Quizzes software used square brackets to delineate the student answer fields in the fill in the blank question. Another item to note is that all possible answers are displayed at once, as opposed to selecting using a drop-down option to pick the possible answer. In Figure 7 there is a presentation of the top-down view between formulas in new quizzes versus the classic quizzes.
Figure 7: “New Quizzes” Fill in the Black Question Formula Top-Down Comparison
In Classic Quizzes the delivery of Formula Sheets or other textual guidance to students may be delivered using a “Text” question type. However, in New Quizzes the migration of Text questions is mapped to a novel question type referred to as “Stimulus”. Unfortunately, the Stimulus question type has been found to not behave as expected, including not being viewable to students when taking the assessment. In Figure 8, a summarization is presented on all the discoveries found in the analysis performed with live test of the “New Quizzes.”

III. Updates Known to Be Required to Responses within “New Quizzes”

Various aspects of the correct responses which were previously working in “Old Quizzes” may require some revisions to score correctly using “New Quizzes”.

- **Case Sensitivity** within (Fill-in Multiple Blank) FMB and Fill-In-Blank questions: it appears that at least in some cases, students who submit “B” do not receive credit if the correct response is entered in canvas as “b”. Although it worked previously the only known work around is to manually enter both upper and lower case versions of the correct answer for all questions delivered to students using these question types.

- **Improper Answer Mapping after Migration**: Some cases have occurred in FMB type questions where after Migration answers have been assigned to different questions than they were intended. In other words, the “Old Quizzes” had answer “c) 31 seconds” for part 1 and “g) Approach X is preferred” for part 2, but after migration the “New Quizzes” had answer “c) 31 seconds” for part 2 and “g) Approach X is preferred” for part 1.

- **Histogram of Scores**: it has been observed that the histogram generated in Reports -> Quiz and Item Analysis in “New Quizzes” does not represent the scores that students actually received.

Figure 8: Suggested Updates to “New Quizzes”

The second to last section in the Canvas “New Quizzes” Primer document states the experience with migrating IP restricted quizzes to New Quizzes as of November 2022, when features such as previewing the quiz as an instructor was locked to the IP restricted network, forcing instructors to either remove the IP restriction or join the specified network prior to viewing the quiz.
IV. IP Restriction in “New Quizzes”

Various settings in “Old Quizzes” may reside on different screens in “New Quizzes”. One important case is the IP restriction to lock your assessments. That is now located in the Build → Settings command flow. The following vital points are conveyed:

- Please note the following IP addresses must be indicated PRIOR TO publishing a “New Quiz” to be delivered in the EPC: 132.170.213.111 and 132.170.213.27
- Additionally, once a “New Quiz” has IP restriction set, it cannot be “previewed” anywhere except in the EPC; please note that the screen will hang with a spinning circle indefinitely and never respond nor post any feedback.
- Furthermore, once there are one or more submissions to a “New Quiz” then it cannot be unpublished.
- Therefore, at present no method has been identified to be able to “preview” a quiz once a student makes a submission.

Figure 9: “New Quizzes” IP Restriction

Concluding, at present no method has been identified to be able to “preview” a quiz once a student makes a submission.

Assessment-Based Remediation Framework to Optimize Earning of Micro-Credentials

The protocol that was developed allows students and peers to come together for a targeted tutoring and grade remediation sessions. These sessions allow students to gain soft skills by expressing in-person to undergraduate teaching assistants why they deserve points back on an assignment. In addition, this allows TAs to interact with students in an informal manner to get insight on how the course may be improved based on student opinions.

In organizing the flow of providing grade remediation and tailored tutoring to the EEL3801 Computer Organization course, a workflow was developed and integrated. The workflow provides easy implementation for the instructor and teaching assistants while providing a supportive peer-based torturing scheme. The tutoring and remediation flow rolled out, received well rounded
remarks by the students and teaching assistants as it works smoothly in the course. In the case that the assistants job credentials do not have grade access, the following workflow was seen:

1. A **View-doodle** for students to asynchronously schedule tutoring appointments was developed. The implementation allows for students to have guaranteed times upon which remediation and tutoring will happen, while also providing the teaching and or learning assistants to prepare for the incoming student.

![Figure 10: Rebuttal View-Doodle](image)

2. The utilization of the university provided cloud service, allowed for a **OneDrive folder with encryption** of the Canvas digitized quiz and of the scanned in scratch sheets by the GTA for the course (Paul Amoruso). The encrypted database allows for a FERPA cognizant flow, by ensuring that the undergraduate learning assistants do not have privilege to view students’ scores without the student providing the secret decryption passcode that is shared between the GTA and student. Each file is saved with a randomized code that is known as the student code, that changes along with the password every quiz-based assessment.
3. The GTA confirms the students’ appointment via a **knight’s email** to student which contains the student code and decryption password. This provides a FERPA-cognizant workflow that was tailored and developed for the *BC-Eco*.

4. When student for tutoring arrives in-person, then the **submission is decrypted by the student and score is clarified with tutor**. To decrypt both undergraduate learning...
assistant, and student must be present simultaneously, as only tutor has encrypted quiz and only student has decryption password. Thus, there is a check-and-balance system to allow that the questions cannot easily escape as encrypted except during in-person review session, and that tutors cannot view grades without the student providing a passcode.

5. **Tutor Feedback Spreadsheet on OneDrive** captures the discussion and outcomes. It is shared only among GTA, instructor, and tutor, and only GTA knows the student code they assigned. Figure 12 shows the in-person tutoring sessions work very well in providing a report of the students that received remediation and feedback by the tutor. With the use of the tutor feedback spreadsheet, an audit trail is provided to both the GTA and tutor to look back to.

![Figure 12: FERPA-Cognizant Point Tracking and Feedback by Tutors](image)

Remediation is the opportunity for instructors and TAs to target and remediate selected skills, while providing the students to postulate recommendations about the course on a one-to-one conversation with the TA’s. The recommendations will go to the instructor to help provide a tailored way to teach the students. Table 3 provides a layout of various values that appear to
indicate the importance lecture closures had has on the students receiving digital badges. In the Spring of 2022, nearly half of the students in enrolled in the course received at least one digital badge, yet the trend was not met at the expected rate in the following semester. The reasoning for this, could be for various reasons. One of the main differences that occurred was due to the unexpected number of lectures that were canceled due to various holidays, university events, and hurricane Ian closure. In addition, students were tested on a New Quizzes format for the second quiz in the course that graded many students’ quizzes inaccurately. In addition, the research framework does not support the analyzation “New Quizzes,” which prevented the tracking of student performance on the second quiz for EEL3801 Fall 2022. Resulting in the inability to prove student comprehension of the eight possible skills in the second quiz in the Fall of 2022.

Table 3: Correlation Between Number of Badges Dispersed, Enrollment, and Lectures Closed

<table>
<thead>
<tr>
<th>Course</th>
<th>Number Enrolled</th>
<th>Number Completed</th>
<th>Number of Badges Dispersed</th>
<th>Lectures Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEL3801 Spring 2022</td>
<td>70</td>
<td>66</td>
<td>39</td>
<td>11.11%</td>
</tr>
<tr>
<td>EEL3801 Fall 2022</td>
<td>122</td>
<td>112</td>
<td>37</td>
<td>26.67%</td>
</tr>
</tbody>
</table>

The work on remediation seen with the integration of a micro-credentialing framework was built upon previous works on the approaches for integrating remediation in digitized STEM assessments. Indicating that remediation can reduce 43% of the lowest letter grades in the course [3, 37]. In addition, various works have been attempted to increase student motivation of learning.
course topics, such as allowing students to take quizzes multiple times in a week span, and the implementation of additional video-based lectures to watch at the students’ own pace [38, 39]. The implementation of a repurposed computer lab to a secure testing center and remediation room, allowed instructors to join a new age of testing in STEM with a proctored setting allows for the decrease in cheating while benefiting multiple courses from digital testing [40, 41, 42, 43]. To address the concerns with conventional weekly lab reports, learner portfolio was used to elevate the student’s attention toward ingenuity along with a novel eight-step phased instructional flow with various adaptions allowed STEM Blended Delivery Protocol platform for hands-on problem solving to trace test score validity, learning achievement, and student perceptions [44, 45, 46, 47]. Integration of allowing students to volunteer in advancing soft skills by videoblogging and group crowdsourcing is one of these techniques integration that allows for students to grow soft-skills and increase knowledge with 71% of students agreeing that the tools/procedures were easy to understand [48, 49, 50, 51, 52, 53]. Thus, the start of the NSF grant research on micro-credentialing was founded upon the idea to incorporate the goals of digitized assessments and peer learning. The fundamental premise and hypotheses that by using student assessments responses, a fine-grained resolution is enabled to pair students into remediation peer-learning cohorts to optimize learning [54].
CHAPTER FOUR: INSTRUCTOR-FACING MICRO-CREDENTIALING

USER INTERFACE: FOUNDATIONAL RESEARCH, OPERATIONAL OBJECTIVES, AND PROTOTYPE

The project goal is to research and develop an optimal solution to the requirement for an instructor-facing micro-credentialing user interface. The project is building upon foundational research that utilizes student submissions in canvas, to assess and disperse badges that pertain to skills obtainable in the course. Instructors that want to integrate the use of micro-credentialling in their courses must be able to assign skills to individual questions as well as receive useful data in an easy and useful manner. Thus, making it integral this project can allow the foundational research of micro-credentialling into a real-world usable product. The seemingly most reasonable way to achieve the goal was to begin with the already Python-based toolset which was developed prior to this project but only used as a proof of concept and extend it into a full user-accepted micro-credentialing tool. A detail the steps of this extension in the following sections. The outcome of the project will allow instructors to not only better manage how or what they focus on in the course, but also allow for more targeted tutoring by being able to identify and fill knowledge gaps of at-risk learners and disperse badges to reward high achieving students to display the skills received in the course. The development of said project is dependent on taking the already developed work on micro-credentialing and grow it for utilization among various STEM instructors.

In starting the project, the first step is to investigate the wishes the ideal user would want to have. Using the direct guidance from two University of Central Florida (UCF) professors
throughout the development of the project, a prototype user interface was created. In the initial informal survey of what would help in the process of micro-credentialing Dr. DeMara, Pegasus Professor at UCF and advisor to the author, suggested that he would like to see a graphical user interface to tag skills with questions and display a visualization of the overall performance per skill after students have completed the quiz-based assessment. The application that tags skills should have a very simple interface which consists of traversing all the questions in each quiz and having the functionality to select multiple skills per question. Then for the feedback portion, there is an application that provides a visual representation on where the class excels and or lacks in the possible skills achievable. The initial version of the applications was shown to another Professor at UCF, Dr. Ozlem Ozmen Garibay, for reviewal and guidance. The recommendations given consisted of having a more user centric design, as well as pushing the feedback of skills in a more concise manner, rather than simply a pie chart. The main challenge that the project aims to resolve is the fact that many instructors are not inclined to interact with Python scripts, and or mundanely go through the matrix with questions to tag skills to each question. Therefore, the main goal is to make a user-friendly application that requires relatively little learning necessary to operate successfully.

In developing the application, we built upon the coded algorithm already developed in prior iterations of this research by adding the Tkinter package, which was selected because it is a standard Python interface to the GUI toolkit [55]. A portion of the project development consistent of learning how to seamlessly integrate the GUI framework in the preexisting python scripts that has the logic to develop a matrix and assign badges to students. With constraints on knowledge to
develop a user interface in the given programing language, our design includes a JSON file for instructors to enter an access token, and skill names for the application to use, rather than having the application ask for fundamental information every time the instructor starts it. The system presented is the finalized structure for the version one of the user-interface, which is ready for beta testing prior to full deployment.

Micro-Credentialing Framework

Micro-credentialing is currently a lively area of research within recent years. The drive to utilize micro-credentialing is due to its ability to innovate the field of education, by evaluating skills students obtained that go beyond what current grades and or assessment scores offer to instructors. The user-centric interface implementation builds upon is an open-source NSF project aimed to develop measure student performance and disperse badges in a manner that has not been achieved prior. The context in this framework, is to data mine various key information from the assessments in the LMS (learning management system) to award digital badges to students that show comprehension of topics seen in a course.

The applications that make up the structure in the framework consists of two main programs utilized throughout the semester, which are to extract questions to tag, and calculate student performance in skills. There are three main phases that can be used to simplify the overall process. The first phase is the extraction phase, which is required to extract the questions from Canvas LMS, to develop a data matrix that is further used to tag with skills. The second phase is the credentialing phase, this is the backbone of the project, as it encompasses the traversal over the
matrix of questions and student performance to assign the skills for each assessment to the students. Then the most recognizable phase is the reporting phase; this encompasses the badge dispersals with overall student-by-student report of each skill. Given the framework to tabulate, calculate, and present student performance is highly dependent on matrixes that the user interface is hiding, the title “MUI” was coined as the title for the matrix user interface.

![Figure 13: The Matrix User Interface (MUI) Overview](image)

**MatrixMaker**

In developing the application that is synonymous for the extraction phase the name “MatrixMaker” was coined, due to the systems reliance on a data matrix that is used to tag skills to each question within the assessments. The idea with developing the application, was to have some way of extracting questions from canvas to store in a way that skills can be visually tagged to questions. As with most projects, the goal is to achieve a functionable product as a proof of concept, prior to putting into ease of use for non-technical users. Therefore, the initial design was
dependent on a “script overseer” such as a graduate teaching assistant with programming experience, to run the applications via accessing the source code. In order for the data mining to progress, the application needs to have access to the Canvas LMS. This means that the user would have to input a bearer access token, and URL course specific values to the source code. In addition to this, the user would have to manually open the matrix of questions to tag each question with skill(s). There were two main problems with this, first, the user would have to feel comfortable with modifying Python programming language code, and the second issue, is that the person who is tagging the questions must make sure that the skills are typed in correctly without any accidental characters. While this did the job when done correctly, it took an experienced individual, with time to spend verifying all tagged skills were inputted correctly.

Implementing the User-Interface

Illustrated in Figure 13, the goal of Chapter Four is to present the implemented design which aims to have a more streamlined approach that makes the application viable to a greater number of instructors. While designing it became clear that the most time consuming and most error-prone portion of the system is tagging the skills to the questions. Therefore, since the MatrixMaker is directly responsible for creating the data matrix upon which skills are tagged to questions it made sense, from both the user and developer points of view, to build a user interface that integrates with the tagging of the skills to each question. This is important for two main reasons, one the user no longer has a potentially huge data matrix that is relatively unpleasant to
view on a question-by-question basis, as well as mentioned earlier, the need to input text into the cells in the matrix to correlate skills to questions.

When modifying the application, there were a couple main focuses in mind, the first was to make sure that the application was easy to use, and that it was relatively simple in design. With the demand to have the first version available within little less than four months, it was integral to have a simple design for development. After discussing with advisors that are the targeted users of the product, as well as reviewing what was most reasonable on the development side, the product would consist of a simple page that displays a question and an option to select the skills that apply. Therefore, the user interface only needed to display the question, present all the skills as check buttons to select all that apply, a next button, and a quit button.

Figure 14: MatrixMaker Interface
Seen in Figure 14, the MatrixMaker application is a very simple and universally understandable interface with UCF school colors. The flow that the program uses, is that it starts with the first question in the assessment and lists all the instructor specified skills for the course with check buttons. The idea is to have the user iteratively traverse each question in the specified assessment through the interface scene in Figure 14. Keeping with the initial idea for tagging questions, the user interface is continuously updating the matrix of questions with their specified skills behind the scenes. If the user wishes to edit or view the matrix, they are free to, however this graphical user interface was designed with the intent of minimizing direct user interaction with the matrix or code. When developing the interface and conducting informal interviews with target audiences, there were some variabilities in opinions on how the design should have been. However, after trying to make a product that pleases most, the individuals that were consulted agreeably came to a compromise. For instance, one such individual, wanted to drag and drop skills to a column on the screen to tag the questions one at a time, while another wanted to have a check button with the skills and see all the questions at once. Thus, the compromise was to display one question at a time and have check buttons.

SkillAssigner

The “SkillAssigner” was coined as the name of the second application that is continuously ran throughout the course of the semester for each assessment, as it follows the MatrixMaker after students have taken the given assessment. In the foundational work, the SkillAssigner was developed to mine the student statistics on performance for a given assessment, calculate the skills
if any for each assessment, and output a matrix with each student and what skills they demonstrated (if any) for a particular quiz-based assessment. As mentioned with the MatrixMaker, the SkillAssigner also required the user to have experience to specify the given assessment in the source code. In all, the SkillAssigner did its job well, as the main role was to perform the calculation, and output the student’s performance in terms of the skills that were demonstrated in a particular assessment. However, it is noted that while it is nice to have each students’ skills in the assessment be accessible, it is hard for an instructor to gage the overall course performance with a list of students and their skills.

**Presenting Overall Performance**

In building upon the given framework to not only have a user centric system but also a system that facilitates the goal of improving education. A survey was conducted to assess the features that would help instructors manage the course. Out of eight instructors that were surveyed in terms to what they would want the SkillAssigner provide, all of them stated that having an easy to view graphic displaying how the whole class is doing would be most ideal. Given the feedback from the participants, a pie chart is dispersed with an update to a dynamic log that displays the course performance for each assessment the SkillAssigner was ran on.
Figure 15: SkillAssigner’s Summary Result View

In addition to the implementation of a visually pleasing pie chart, it was stated by an instructor who focuses on human-computer interaction, that pushing the post important data to the user is fundamental to the process of user acceptance. Consequently, aside the pie chart has the highest and lowest achieved skills from the course to make it easier for the user to gather the most important statistics faster than tediously traverse the statistics. Accompanying the pie chart is a data matrix represented in Figure 15 the file consists of a column of all the skills for the course, and the preceding columns consists of the quiz-based digital assessments the application was ran on. The SkillAssigner application was developed to make the matrix of class overall skills to be dynamic, in the sense that if the instructor decides to add another skill for assessment, the skill will be appended to list of already listed skills. The idea is to have a visual presentation of the class performance that is consolidated to a pie chart and matrix file that is appended to throughout the semester to track class performance as the instructors manage the course.
Automatic Dispersion of Digital Badges

To disperse digital badges to the students at the end a course, the manual specification of skills and quizzes from the MatrixMaker was developed upon. To solve the need for instructors, interact with the code, utilization of a JSON file as used to so the instructor or user may specify the credentials to access the data in Canvas and the corresponding skills for the assessment. An example of a potential digital badge a student in EEL3801: Computer Organization may get awarded is shown in Figure 16. The MatrixMaker and SkillAssigner require the token, URL, and skill options. However, the dispersion of emails tailored to each student with the skills obtained requires a full name of the skillsets and link to the digital badge, giving birth to framework linking the URLs to each potential skill. Comparably, Table 4 catalogs the badge name, link to the badge, and its category.

![Figure 16: Data-Path Design Badge](http://cal.ucf.edu/iusehsi)

Figure 16: Data-Path Design Badge
<table>
<thead>
<tr>
<th>Badge Name</th>
<th>Link</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory capacity, hierarchy, and storage devices</td>
<td><a href="https://tinyurl.com/memorycap">https://tinyurl.com/memorycap</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Digital signal communication, busing and Interfacing</td>
<td><a href="https://tinyurl.com/digitalsignalcommun">https://tinyurl.com/digitalsignalcommun</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Processor Performance Metrics, and Benchmarking</td>
<td><a href="https://tinyurl.com/ProcessorPerform">https://tinyurl.com/ProcessorPerform</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Instruction Encoding and Datapath design</td>
<td><a href="https://tinyurl.com/datapathdesign">https://tinyurl.com/datapathdesign</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Integrated Circuit materials and Fabrication</td>
<td><a href="https://tinyurl.com/integrationfabrication">https://tinyurl.com/integrationfabrication</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Floating-point and numeric intensive acceleration</td>
<td><a href="https://tinyurl.com/floatingpointintensive">https://tinyurl.com/floatingpointintensive</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>In circuit emulation and debugging</td>
<td><a href="https://tinyurl.com/circuitemulation">https://tinyurl.com/circuitemulation</a></td>
<td>Discipline Skill</td>
</tr>
<tr>
<td>Metrics of Performance and/or SI Units</td>
<td><a href="https://tinyurl.com/MetricsSIUnits">https://tinyurl.com/MetricsSIUnits</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Energy Analysis or Conversion</td>
<td><a href="https://tinyurl.com/Energyanalysisconversion">https://tinyurl.com/Energyanalysisconversion</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Computational/Algorithmic Thinking</td>
<td><a href="https://tinyurl.com/ComputationalThink">https://tinyurl.com/ComputationalThink</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Conduct Directed Design Process</td>
<td><a href="https://tinyurl.com/direct-design">https://tinyurl.com/direct-design</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Conduct Open-Ended Design</td>
<td><a href="https://tinyurl.com/Openendeddesign">https://tinyurl.com/Openendeddesign</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Conduct Tradeoff Analysis (A vs B)</td>
<td><a href="https://tinyurl.com/trdoffanalysis">https://tinyurl.com/trdoffanalysis</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Logic / Operational Flow Analysis</td>
<td><a href="https://tinyurl.com/operationallogicflow">https://tinyurl.com/operationallogicflow</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Engineering Life Cycle (Reliability, Maintainability, Practicality)</td>
<td><a href="https://tinyurl.com/EngineeringLifeCyc">https://tinyurl.com/EngineeringLifeCyc</a></td>
<td>Theoretical Skills</td>
</tr>
<tr>
<td>Data/Info Representation</td>
<td><a href="https://tinyurl.com/DataInfoRep">https://tinyurl.com/DataInfoRep</a></td>
<td>Applied Skill</td>
</tr>
<tr>
<td>Tools for Simulation / Emulator / MATLAB</td>
<td><a href="https://tinyurl.com/Toolsforsimulation">https://tinyurl.com/Toolsforsimulation</a></td>
<td>Applied Skill</td>
</tr>
</tbody>
</table>
The methodology aims for the badges to stay concise and visually pleasing for students to proudly display. For instance, the badges made for EEL3801: Computer Organization with Pegasus Professor Dr. Ronald DeMara consisted of 17 badges of identical design that distinctly specifies the skill in a digestible format. Hosting the digital badges online permits the students to add the received badge to a supportive feature within LinkedIn. Each receiving student gets an email that has an attached instructional guide for LinkedIn with a link to the awarded badge.

**Evaluation and Results**

The evaluation consisted of various University of Central Florida STEM instructors that resembles the target audience for the micro-credentialing system. The key features that are shared amongst the instructors that were survey, are that they are all in STEM, invested in improving higher education, and currently or planning on implementing digitalized quiz-based assessments. The responses collected via the instructors consisted of answers to four survey questions, which involved asking the participants that they would rate the user interface from one to ten, the likeliness of implementing the system in their course(s), comments, or suggestions, and if they have seen any similar product or service. The survey revealed that 50% of the participants rated the user experience a 10 out of 10, 37.5% rated it a 9 out of 10, and 12.5% rated it seven out of 10. Overwhelmingly 62.5% of the participants stated that they see themselves “highly likely” and the other 37.5% said “likely” to use something like this in their course. The most interesting responses came from the participants comments or suggestions. For instance, one participant stated that they see this framework as a tool that could be used to highlight skills in a course to be public to
students, for making the course selection process simpler on the student side. More specifically, the participant stated that “this could help to fill the knowledge gap for those students who do not have some of the skills needed for the course and skip concepts that they are already familiar with.” Moreover, another participant stated that “the ability to tag questions with skills is novel. Displays created also highlight top-level outcomes which are of interest to an instructor. These features support UI capabilities which I would want to utilize and do so in a direct and usable format.” Then finally, all the participants stated that they have not seen a similar product or service.
CHAPTER FIVE: CONCLUSIONS

Technical Summary and Insights

Micro-credentialing was proposed as a solution to limitations associated with targeted tutoring and knowing what specific skills students have after taking STEM courses. Motivated by the support of instructors in various departments in the university, and attempts made by related work with companies developing platforms that associate skills to modules or assessments, and research approaches that focus on student engagement on course topic material. In this approach, all programming operations are done using the data mining approach, which consist of functions such as API requests to collect and store necessary data from the course that consists of user information, assessment questions, and student statistics on the assessment. In addition, a fuzzy approach was utilized to assign badges to students or to classify other features that can help instructors and the industry. Using the fuzzy and data mining approach was in response to improve the related works methodologies and give grounds to a fundamentally more data hungry approach with machine learning.
The micro-credentialing research was developed and tested through a couple semesters, and among that time, badge dispersal was implemented to reward high achieving students that deserve recognition on the skills they obtained in the course. Micro-credential badges give students something to look forward to throughout the semester as achievable goals, this also gives students with the ability to promote themselves in the industry to employers after acquiring digital badges from a course. In two separate semesters and observed that about half of the students were qualified enough to receive at least one badge to say they were proficient enough to claim proficiency in a particular part of the course material in the first semester.

Figure 17: Thesis Direction Overview
In continuation with developing a greater understanding of the connection between the students receiving badges and the course points they received throughout the semester; Figure 18 displays a visual representation of a statistical analysis. Given that the analysis may vary slightly from course to course, it is important to understand that while the highest achieving students receive the greatest number of badges, other students with a lower grade were still able to retrieve badges on topics that they excelled in.

Finally, a customized user interface for instructors using the micro-credentialing applications was developed to garner larger traction amongst instructors of all skills. Estimated results indicated that majority of the users have not seen similar products and could see themselves using it.
The thesis flow is summarized in Figure 19.

![Diagram showing logical organization of this thesis]

Figure 19: Logical organization of this thesis

Technical insights gained from the work presented herein are summarized below:

- Skill tagging of questions can offer significant benefits in terms of globally scaled credentialing throughout a course.
- The credentialing of students incrementally allows for the tracking skills and the remediation process to work hand-in-hand.
- The instructor-facing micro-credentialing toolset along with user-interface was surveyed and received interest among various instructors wanting to implement the software, with 37.5% and 62.5% of instructors stating that they are likely and highly likely to use it respectfully.
- The micro-credentialing toolset that was developed is over 400 lines of code for each of the two major scripts with various conditional logic, making it largely dependent on the technology that the data is collected from.
- Aiming for minimal invasion to integrate within courses, gave a seemingly upper hand in usability and customizability compared to the major commercial products. Which was commonly heard when presenting at the OLC Accelerate 2022 Conference on Accelerating Online Learning Worldwide.
Scope and Limitations

The work this thesis covers brings light to various future works while highlighting the ability that micro-credentialing in STEM courses has. Ideally micro-credentials can be assessed and dispersed without adding additional steps in the students’ academic already busy workloads. Instructor facing ideally micro-credentials will be automated from an instructor point of view so the instructor can concentrate on student learning rather than determining the eligibility of each students’ credentials. Administrator privileges within the LMS is a known hurdle that other solutions face, along with tagging skills to questions, and the time it takes to develop digital badges is one of the potential future problems that will be addressed. The opportunity for an instructor or tutor to target and remediate selected skills, provides the opportunity to have a one-to-one conversation with the students to gather new perspectives on how the course is received on the student-side. The recommendations students bring, will help provide a tailored way to teach the students. The developments that are presented were with the intent to work the best around the limitations facing such a product. This means, that simplicity was in sight throughout the development phase. One of the most notable disadvantages this work brings, is that the work has a technology investment that has the potential to require upgrades in later versions. Currently conversations have been held with UCF’s Center for Distributed Learning to present a framework to build upon in implementing a reasonable micro-credentialing aspect to LMS.
Future Work

The advantages of micro-credentialing and developed tools aim to help instructors and students improve the education process is promising and open doors for several interesting research questions, including:

- How would the performance of the scripts be affected when implemented university-wide using a fuzzy technique or a machine learning approach?
- By determination of students’ skills, how can it be implemented to provide ease to students deciding and selecting future courses?
- What architecture design is best for an unsupervised machine learning algorithm approach to tag skills? For example, how many layers, neurons, or activation function should be used, to benefit the most?

Recommending Remediation-Based Videos to Support the Filling of Knowledge Gaps

Regarding future works of providing students to video segments for furthering the remediation protocol provides a potential for video recommendation based on assessment performance. The idea was started when observing the trends in what student’s desire when preparing for a course. Most times students search YouTube videos on the respective subject to supplement any material they missed out on with the instructor. However, rather than leaving the students to spend unnecessary amount of time searching for supplemental videos, have the instructor provide a library of videos that contain adequate information that can be recommended to the students. The general plan is to have instructors pick a library of videos that teach the necessary information
students need and run an application that runs similarly to the micro-credential applications but looking at the questions that were incorrectly answered by the student for recommending video clips.

After the instructor has identified a list or library of videos from the user will run the `youtube.py` application which will take in a string that can be found at the end of the URL such as the string highlighted in this url: https://www.youtube.com/watch?v= Ry_3icw168c. The script uses a python API which allows the program to acquire transcriptions and subtitles from videos on YouTube site. With the given string, the script proceeds to fetch the transcript data, and save the transcript in English to a text file. This file is then divided into sections and saved into a folder directory to be processed by the second application once all videos are identified and proceed with the `youtube.py` script.

The AMP algorithm first requires the code seen in the video URL, once that is received, the algorithm does an API request on the video to get the available transcript. The algorithm iterates over all the available transcripts, and details such as the languages available and whether it was manually created or generated by YouTube. It will then fetch and save the transcript data that contains a time stamp to a .txt file to be used if needed later. The program then divides the transcript into three sections. The number of sections started as an arbitrary number based on observing various video lengths and the amount of time an important topic is discussed, however, made sense to organize the transcript into beginning, middle, and end of the video. Making the videos divided by beginning middle and end time stamps. Each segment is saved in a
directory called “scripts” as individual .txt files with naming conventions processed as “scripts/<video_id>_Partx.txt” where x is either 1, 2, or 3.

Figure 20: Transcribing Flowchart for the video-based opportunity for instructor to target and remediate selected skills.

Furthermore, fuzzy matching operations are carried out using a string-matching algorithm that is built upon the Levenshtein distance to derive the difference between strings [56,57]. It often works by computing the number of edits that must be done on a given string to convert to the compared string [58]. Therefore, the script that was developed uses the directory made in the process of collecting transcriptions to traverse the matrix of questions used in the MatrixMaker application to tag each question with the video segment that closely matches it. With the tagging
of questions and answers in a quiz-based assessment with video segments, we are then able to perform a traversal process of student performance on the assessment to recommend videos to watch based on what they got wrong.

The process in which the algorithm flow starts by going to the “scripts” directory to collect the .txt files which store the transcripts. The program then stores the script segments in a Python dictionary prior to starting the loop which will compare each question to each transcript. The loop starts by opening the CSV file that contains columns for questions and answers, where each row represents a question and answer that will get cross checked to identify the video that best represents the material to study from. The ideology states to get the top three video segments for each question and answer and then cross check from the two sets to identify the most suitable video clip to tag to the question. Once the process completes, the file is saved as a .csv file and is available to further process of looking at student performance for recommendation purposes.

Figure 20 shows the process of tagging video segments to a pair of questions and answers; however, it does not address the detailed process to provide the recommended videos to students. In addition, this process that was described is utilizing an algorithm that matches text in a fuzzy manner, rather than developing a machine learning model that can identify the topic similarities between words to smartly recommend videos. The ideal goal would have a generalized model that can smartly decipher the meaning and similarities between words and phrases to improve the ability of matching strings in a way that is close to human capabilities. This model will have to be well trained on some form of lexical semantics to understanding the meaning of the words in the
questions and transcripts, similarly to the advancements seen in natural language processing. Ideally, the matching process can be accompanied with a video recommendation process that is integrated within the Canvas site, for easy to access user involvement. In the meantime, the badge discernment strategy with emailing students can be modeled to this aspect of the research. Therefore, students may get autogenerates emails with list of their recommended video segment links. No matter what way the research goes, the aim is to help students at the end of the day by providing them with the tools to arm themselves with knowledge to do well on the assessments based on their previous performance.

While the current stage achieved has been very functional and unlike other software, the above questions must be answered for future improvements and innovations in the education system. As the LMS evolves and the methodologies the students utilize changes, so does the tools in which the instructors interact with them must evolve.

Scaling Up Processing Demands Expected for Large Scale Deployment

In continuation with future and current implementations, the most recent goal is to present research discoveries analyzing the performance of a developed instructor-facing micro-credentialing application. The analysis of the toolset developed relies on using digitized assessments, to automate micro-credentialing for the Canvas LMS to output skill-specific badges which motivate the learner incrementally, while increasing self-efficacy. The toolset has been developed in previous semesters to allow the automation of credentialing students with skills while providing instructors with a user interface that aimed to garner user acceptance. Therefore, it
seemed appropriate to use recently learned understanding of performance and storage analysis to analyze how the automatic micro-credentialing toolset can perform as data grows from an increase in students and quiz-based digitalized assessments. Moreover, an observation that will be seen in the project is based on the growth of synthetic data given to the framework, to optimistically get insights on what is sufficient or needs improvements before scaling up. In presenting the implementations taken to analyze the performance and size requirements, a backstory on how the application works will be provided, to give a foundation on the benefits and implications this framework brings to the industry.

The problem description is answering what is the storage requirement, and how will the performance of the current software scale as the course or assessment size increases. If the goal of any research is to provide evidence and ideas that can potentially improve society or technology, then it is critical to lay the groundwork for what limitations or benefits there may be to scaling up this research-based product to industry usage capabilities. While the current application runs on the users’ local machines and is not dependent on live attempts of the assessments, the question is how it will perform under various extremes? The reasoning behind stress-testing the framework, is to learn if there are any limitations to the applications if it were to be deployed in more demanding scenarios. The reasoning for the limited knowledge of the application's performance is that it was started as a research project to devise a micro-credentialing digital toolset rather than an industry used product. Therefore, the proof of concept was all that was needed in the early stages of development, whereas now we know that the application has the potential to be added to various instructors' computers to track student performance for their courses and automatically
disperse digital badges to their students. The pre-developed quiz-based digital assessment and remediation protocol, along with a Python-based toolset, was created to engage tutors who tailor their tutoring to at-risk learners based on the application's output. The problem with previous framework tools was that they were not designed with performance in mind, necessitating this analysis.

The performance analyzing project builds upon derives from personalizing digitized assessments, personalized tutoring, and automated micro-credentialing scripts for the Canvas learning management system (LMS) to issue skill-specific badges that motivate the learner incrementally, while increasing self-efficacy. Thus forth, my work is on developing the technical toolset for the base of the triangular framework you see above. Which consists of developing Python scripts that data-mine from assessments such as quizzes and tests for creating more personalized tutoring, as well as providing high-achieving students with additional badges they can advertise for future employment. In previous semesters, a user interface was developed for the micro-credentialing software, to allow STEM instructors to need no knowledge of coding, and only require the use of digitalized quiz-based assessments on canvas LMS to use the application. Before scaling, one must first understand the current limitations that the application has. Therefore, there will be two main portions that will test the scalability.

- Storage Size Requirements: By testing the capacity, we can identify how many courses or files the server can store. Based on the size of the local machine, it possible to gauge the total size requirement of the application before more storage is necessary. To have a fair analysis, the research will utilize a computer that was received to the research
laboratory as the closest standard to what the university instructors are given. Thus, a Windows 10 desktop that is provided by the university, will be used to control the experiment. For instance, if the application requires about 69.4 MB for one assessment with about 120 students, then how will it scale as the number of students and assessments increase in size, is potential to calculate.

• Performance Time: As new synthetic data is added to the system and various test cases are implemented, the execution time will be analyzed multiple times on the same system to ensure accuracy. There are multiple commands and applications that are often used to analyze execution time. For example, PowerShell includes a Measure-Command that can calculate the time it took the application to run [59]. However, because the micro-credentialing application includes user interaction, the total time the application runs is not universally accurate and thus not very reliable. This means a smarter, more tailored approach is necessary to analyze the run time. Furthermore, the source code will have to be modified to integrate the use of the time.time() Python programming language function, or a similar function, to analyze the total time the script took to perform various tasks, such as querying the database.

By explaining the various developments in the evolving micro-credentialing solution, it will become clearer how it can be implemented to reach the masses, and or scaled up to provide cloud products. The project plan is to have a technical investigation of the Canvas-based micro-credentialing framework developed and integrated into a required undergraduate-level computer engineering course, by measuring the storage size as the database grows with the number of
students, the execution time as the database grows with the course size and performing an overall stress test on the framework to provide future direction. The expected output will have main graphs indicating the size requirements as the number of students in the course increases and the number of assessments increases, and a graph showing how the application performs in terms of run-time as this synthetic data is increasing in size. The purpose to use synthetic data derives from the fact that these tests will be sandboxed to apply large variable changes when measuring the data points.

The project plan will be constrained to the length of the EEL6762 Performance Analysis of Computer Systems course, as a course project. Therefore, the plan will consist of the first week to prepare and present the project proposal presentation. The following week will consist of finding more conference papers or related technical sites to reference various ideas that may improve the project plan while also calculating the typical size of csv files generated by micro-credentialing toolset. The third week of the project will comprise of identifying and implementing functions in micro-credentialing source code to analyze run times of various tasks. Week Four in the course project will quantify how many courses, assessments of a typical size, and or students it will take to fill the remaining 1.73 Tera Bytes on the local research laboratory computer and enumerate how the storage size will scale to instructor machines. The fifth week is when starting to draft introduction paragraph of the research paper and decide on the main comparisons to include and start developing a table of results to compare database. Week six the continuation of drafting the final report with what was gathered on the performance analysis of the applications and the technology comparisons and implementations. Week Seven of the semester project the start of writing discussion and conclusion regarding the results that plan to have gathered within the final
project report. In the eighth week of the project, the aim is to conclude the optimal method to store data and query technique, present figures or charts stating the requirements needed to scale up the micro-credentialing software, and list potential databases or code to improve the credentialing and tagging application. Week nine of the course project is planned to be the week when it is time to ensure that final draft of survey is completed to allow for presentation rehearsal. Finally, start of rehearsing for final presentation, touch up the final draft of the research presentable paper, ensure that project is submitted, and final presentation on week ten and eleven.

In conclusion the research project will observe how performance is affected with the number of students and assessments in a given course. The calculation portion will mainly deal with mathematically expressing the storage requirements for various size classes and assessments. The aim is to understand the performance limit with the type of tasks the application performs to see whether there are any bottlenecks, by using a consistent run-time investigating tool. Essentially, a whole performance evaluation with the current setting, including the server hardware, and software, is necessary. Other than just understanding how the application performs under a stress test, the goal will also be to review for possible improvements by potentially using data analytic benchmarks. Accordingly, from a performance perspective, it can be concluded the current performance, via observing how large the CSV file is and how long it takes to parse it. Meaning that the analyzation for scale-up project will quantify how large the files may get before having to use big data techniques in addition to execution time. Overall, before scaling up, an understanding of the local size and performance constraints must be known.
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