Journal of Engineering Education Transformations,
Volume No 36, January 2023, Special issue, eISSN 2394-1707

10.16920/jeet/2023/v36is2/23014

Sustainable Data-Centric Project Curriculum for Industry-Ready Workforce

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***Abstract*—The emergent technologies such as Artificial Intelligence, Deep Learning, Data Analytics, Blockchain, and Data Visualization have created an urge for the entry-level workforce to stay up to date with the industry's analytics requirements. Since it is evident that the growth in technology and innovation rapidly changes the nature of data-centric jobs, organizations must put in a lot of effort to train their employees, especially in cloud-based sustainable work environments. Aligning academic curricula with industry requirements has been a necessity more than an option for providing sustainable solutions. Therefore, academia and companies should work together to address real-world challenges, saving a lot of money, time, and effort along with tremendous changes in the education sector. The main objective of this research paper is to explore pilot studies by designing project-based courses specific to the data science disciplines for the students by examining current research innovations in technology and industry guidance and collaboration. To achieve this objective, we introduced courses in data science by proposing a Sustainable Data-Centric Project Curriculum. Industry-academia collaboration and offering courses relevant to current technologies play an essential role in cultivating a highly skilled workforce. Offering such courses will prepare students in computing disciplines (CSE, IT, and Data Science) to acquire the data analytics foundation to create an industry-ready workforce.**

***Keywords*— Project-Based Learning; Data Analytics; Industry Preparedness; Curriculum content innovation – Sustainable Data-Centric Project (SDCP) Curriculum.**

***JEET Category*—Research**

I. INTRODUCTION

WITH globalization and digitization transforming the world every day, higher education has a more crucial role than ever before. According to the seasonal data analysis of spring and summer, youth employment by the Bureau of Labor Statistics (BLS) reported on August 17, 2022, 55.3% of young adults aged 16-24 were employed in July 2022, up from 54.4% in July 2021. The employment rate is below 56.2 percent, despite the onset of Coronavirus (COVID-19) in July 2019 (bls.gov, 2022a). However, it is estimated that computer and information technology jobs will grow 13% faster than the average for all occupations between 2020 and 2030. It is expected that about 667,600 new jobs will be created in these occupations. With cloud computing, big data collection, and information security becoming more important, these workers will need greater. The BLS also reports that IT occupations paid a median wage of 97,430 in May 2021, higher than the average wage for all occupations of $45,760 (bls.gov, 2022b).

For educational institutions to be effective, they should not only produce the educated citizens our society needs but also ensure that industry requirements are taught. Research findings indicate that higher education is positively associated with employment rates (Ali Muhammad and Hina Jalal, 2018) and that education and work practices must be integrated to enrich practical understanding (Tynjala et al., 2003, Warrick, Daniels, & Scott, 2010). In other words, higher education institutions must set realistic goals to move from traditional faculty-centric education to a more student-centric approach with the primary objective of producing an industry-ready future workforce. This objective can be achieved through the amalgamation of education and industrial practices.

The authors have extensively examined how cyber learning and student-centered learning environments can enhance students' learning experiences in computer science and education (Ramasamy et al., 2022a, 2022b, 2019). Furthermore, it has become increasingly important to use the appropriate tools and techniques to link student learning with corporates to bridge the gap between corporate expectations and the current core curriculum at universities. Therefore, reshaping higher education to meet the needs of the modern workforce is vital for successful employment. As economic, technological, social, political, and ideological needs evolve, so do curriculums. A contemporary and productive curriculum is imperative in computing education to incorporate new skills, knowledge, and values. Without this evolution, graduates who score good grades could not withstand the industry expectations in the long run. Innovation in the curriculum means incorporating new learning designs to create a more meaningful learning experience for 21st-century learners. Innovations and experiential learning are lacking in the present college education.

As many traditional educational practices have become outdated, it is essential to redesign the learning experiences to be more relevant to current industry needs and cultures. In addition, with a more diverse student population with a wide range of abilities, innovations must also be linked to curriculum goals and be challenging and differentiated to provide a range of employment opportunities.

Innovation in higher education involves updating the curricula with current technologies along the lines of changing needs of industry and society (Barber et al., 2016). The massive demand for complementary training for graduates portrays a mismatch between academic education and industry requirements. The importance of data engineering in the era of big data to extract valuable knowledge and actionable insight from raw data gains is widely acknowledged by industrial experts. Changing curriculum content to meet industry needs is the only way to achieve this.

With the advent of new technologies such as Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Data Analytics (DA), Blockchain, and Data Visualization, organizations can drive more value from the vast amounts of data generated from day-to-day operations. In light of these emerging technologies, entry-level workers are under pressure to keep up with the analytics requirements of their companies. Traditional educational practices have become obsolete and learning experiences should be redesigned to meet students' interests, abilities, and cultures. Technology and innovation are rapidly changing the nature of data-centric jobs, and organizations must train their employees, especially in cloud-based sustainable work environments. A mismatch between academic curricula and industry expectations has caused this imbalance.

Businesses can save more money, time, and effort, along with tremendous changes in the education sector. Many industries like IBM, Buddi.AI, and Zebra Technologies, with leading data analytics solutions, are now ready to handshake with academia to propose credit/non-credit industry-supported courses for students to gain experiential working knowledge. Aligning academic curricula with industry requirements has been a necessity more than an option for providing sustainable solutions. Therefore, academia and companies should work together to address real-world challenges. We introduce courses in data science intending to propose a Sustainable Data-Centric Project (*SDCP*) Curriculum. The main objective of this research paper is to explore designing project-based courses specific to the data science disciplines for students with industry guidance and collaboration. Offering such courses will prepare students in computing disciplines (CSE, IT, and Data Science) to acquire the data analytics foundation to create an industry-ready workforce.

Consequently, the paper is structured as follows. We discuss the detailed background knowledge gathered from the literature about the importance of data analytics and data engineering in industry and the future of technology, as well as the need to change curriculums to meet modern industrial requirements in Section II. A model of the proposed sustainable data-centric curriculum is presented in Section III. The results of the pilot study in two institutions are presented in Section IV, and the paper concludes with a description of future work in Section V.

II. Background

Companies and organizations generate enormous amounts of data through log files, web servers, transactions, and customer records. In addition, social media websites and the *Internet of Things (IoT)* also generate enormous amounts of data. Ideally, businesses should utilize all the data they generate to derive value from it and make informed business decisions.

Due to the unprecedented volume and size of data distributed across systems for organizations to manage, there has been a lack of access to data, which creates silos of information making business decisions more difficult. Given the explosive amounts of data being generated in social, commercial, and educational domains worldwide, it is evident that data analytics and data modeling are now considered to be extremely valuable to governments, businesses, and other organizations.

The amount of data will increase to 463 exabytes by 2025. While only 12% of the data available is analyzed, processed, and used for business forecasting and prediction analysis, the remaining 88% remains unusable (Uthayashankar et al., 2017). Therefore, graduates with data engineering and analytics skills are needed to be produced to bridge the gaps between traditional academic practices and the fast-growing industrial requirements (Thomas et al., 2016). We need to understand the challenges of data analytics to build a data-driven culture in the organization (Herbert, 2021).

It is imperative to build data generation and ingestion platforms that integrate, process, analyze, and visualize data as part of a digital transformation roadmap. By leveraging advanced analytics, machine learning, and artificial intelligence, all data-centric organizations can maximize aggregated data value and increase revenue. The power of data is endless when it comes to ML, AI, and data analytics. Keeping up with the growing amount of data businesses generate requires flexibility, agility, and the ability to adapt to new challenges. In 2027, the global digital market is expected to reach 103 billion US dollars, doubling its size in 2018 (Dmytro Spilka, 2022).

The Business-Higher Education Forum (BHEF) states, "*Closing the data science and analytics skills gap - and enabling organizations to take full advantage of the value of data - will require considerable expansion of strategic partnerships between business and higher education, as well as investments in new talent-development strategies.*" According to the BHEF report, the current industrial demand for data-enabled graduates can only be met by building sustainable, effective partnerships between business and higher education (BREF, 2022).

III. Sustainable Data-Centric Project (SDCP) Curriculum Development

New curricula are essential for promoting innovation in education, as they facilitate the transmission of skills, knowledge, and values to students. Curriculum changes are inevitable to address the economic, technological, social, and political needs of society. To make it more meaningful, in addition to explaining what should be taught, new curricula should also describe how it should be taught. Due to a lack of innovation and experiential learning in the student community, graduates with high scores cannot withstand the industry expectations for long (Rishika, 2021). Therefore, curriculum innovation involves adopting new learning designs that help 21st-century learners learn more effectively.

Educators must rethink practices to make learning experiences more relevant to student interests, abilities, and cultures. Moreover, innovation must be linked to curriculum goals and technology challenges to provide an array of learning experiences for a more diverse group of students. This improvement can be achieved only through changes in curriculum content to meet industry requirements (KiiraKärkkäinen, 2012).

A. Research Goals and Objectives

This study aims to reduce the gap between industry and academia and provide students with better business industrial curricula for their future careers. A hands-on experience with real-time data in industry-based courses allows students to gain a fundamental understanding of core data concepts (such as collecting, cleansing (ETL), analyzing unstructured and structured data, visualizing, modeling, and predicting) to meet current industry requirements (Lennart Buth et al., 2017).

We propose an innovative model for *Sustainable Data-Centric Project (SDCP) Curriculum* with the two-fold objectives as listed below:

1. Prepare students to bridge the gap between academia and industry in terms of the requirements of working with big data technology and tools (Power BI, Tableau, data analysis, data engineering, data visualization, building ML models, and predictive analytics)
2. Collaborate with industry to make students familiar and understand working with industry-based big data applications and make them capable of using appropriate technology to solve specific AI problems.

B. Research Questions and Analysis

We formulate and analyze the following research questions with the objectives mentioned above.

RQ1: What are the gaps between the existing computing education curriculum and business data analytics practices in industries?

RQ2: What are the unique features of the project-based courses proposed to reduce the gap between academia and industrial requirements?

The proposed model demonstrates effective curriculum development by answering the research questions described below.

In RQ1, we address the gap between the existing computing education curriculum and business data analytics practices in the industry.

a) University education prepares students to work with different phases of software engineering projects and data analytics problems by introducing them to a wide range of theoretical and research-based knowledge.
b) Students have difficulty applying their learning (data preparation, preprocessing, and modeling) appropriately to real-time predictive models for business solutions when they work on big data analysis and engineering projects during industrial internships. This problem is attributed to a lack of hands-on experiential learning of big-data research, which is essential to grasp a holistic view of industrial projects. It is, therefore, difficult for them to adapt to industry practices and deploy projects on time.
c) Collectively, these gaps widen due to the following important reasons:
    i. Many students lack access and experience with commercial tools and technologies that involve big data analysis (Hadoop and Spark), which are widely used in industries (e.g., Amazon AWS, Microsoft Azure, IBM Watson, etc.).
    ii. Students' perceptions of industrial practices are mismatched with the real-time working environment, making them less prepared to meet challenges.
    iii. Another factor is that a lack of industrial experience in university faculty prevents students from being prepared for industry requirements. Faculty members can only acquire this practical knowledge through collaborations and training programs between industry and academia.

In RQ2, we discuss recommendations and steps from an academic and industry perspective.

a) Develop innovative curricula and hands-on training that meet industrial requirements with limited commercial licenses (e.g., Power BI, Microsoft Azure services).
b) Prepare students to work with real-time data and solutions by proposing project-based learning courses (e.g., Engineering Design Project, Data Science, and Machine Learning Project) based on recent research articles, textbooks, and available online datasets (Kaggle, Hackerrank, etc.).
c) Request that the industry provide faculty with data-analysis training. Students could be taught cutting-edge technologies such as big data, cloud-based technologies, IoT, and Blockchain in real time. These credit and non-credit courses could be offered in collaboration with industries.

The learning outcomes of the proposed business and data analytics course are given below.

- Analyze business data requirements to improve operations and processes
- Utilize state-of-the-art data analytics and visualization tools in business scenarios
- Apply data analytics techniques to business scenarios to enhance operations and strategy
- Identify business implications of data analytics results
- Share insights derived from data analytics with business stakeholders

C. Benefits of Data-Centric Curriculum

The *SDCP* course curriculum initiative offers a variety of benefits to faculty, and students (current and alums) in academia, industry, and society. Fig. 1 shows the benefits of the iterative project-based curriculum model to academia, industry, and the community. Creating a skilled and competent workforce through academic collaboration helps bridge the knowledge and research gaps in the industry.

A sustainable curriculum and diversified funding opportunities from the industry enable students to gain internships and jobs. As a result of industry-academia collaboration, sustainable business models can be developed, resulting in innovative, cost-effective products and solutions at low cost.

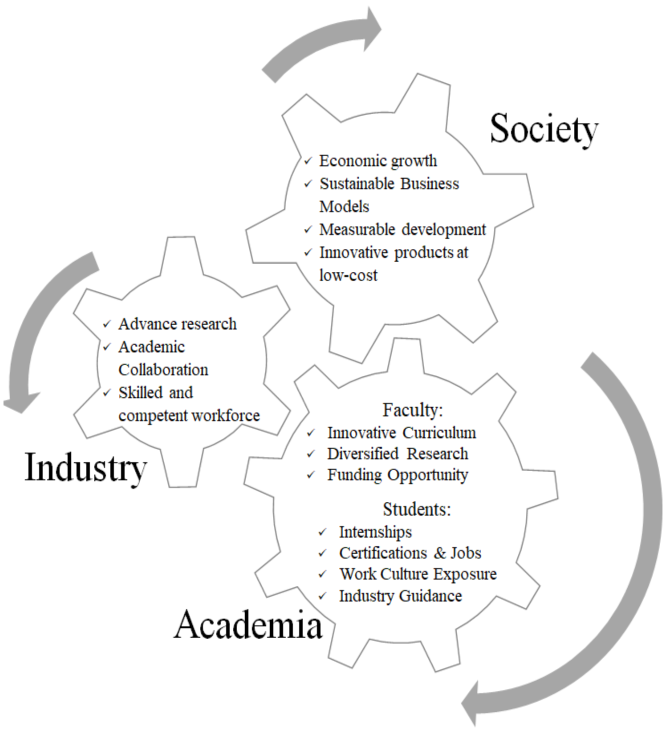

Fig. 1. Benefits of the Iterative Project-based Curriculum for Data-Centric Industrial Model.

Offering a sustainable data-centric curriculum to meet the data-centric goals of the industry is an iterative process. The iterative process workflow to bridge the gaps in the curriculum to meet industry requirements started with the collaboration of stakeholders from industry and academia. The meetings and deliberations helped us understand the new technology the students should be familiar with to ease the transition from college to career.

The benefits of such an iterative project curriculum for various stakeholders are profound (Fig. 1). We also gathered feedback and suggestions from both students who benefited from the courses and industry experts to improve it in the future. The pilot studies were conducted at two institutions to demonstrate the effectiveness of the proposed model. The highlights and the outcomes of the courses are presented in the next section.

IV. Results of Pilot Studies at Two Institutions

The Sustainable Data-Centric Project (*SDCP*) Curriculum workflow we proposed is shown in Fig. 2. It started with the collaboration with industry partners (Buddy.AI, IBM, Zebra Technologies) to investigate the growing data skill gaps and knowledge. Based on the deliberations, we concluded that there is a demand for the core data science skillset, including statistical techniques, ML, data management, and visualization techniques for big data analysis. Through the application of theoretical knowledge (research-based), engineers are expected to solve real-world problems (industry-based). Therefore, students must learn about advanced technologies in data science and analytics to be aware of new job opportunities, evolving technology trends, and future challenges in the field. We proposed two courses emphasizing both research and industry-based curriculum to bridge the theoretical knowledge and the practical implications of the crucial concepts. Two courses were proposed and taught, covering innovative data-centric concepts based on reviewing recent research publications and consulting industry experts to ensure that the courses meet current industry requirements. The proposed iterative Industry-based Project Course model, the details of the pilot studies, and the outcomes of the preliminary analyses are summarized in the following subsections.

A. Sustainable Data-Centric Project (SDCP) Courses - Pilot Studies

Industry-academia collaboration and offering courses relevant to current technologies play an essential role in cultivating a highly skilled workforce. To accomplish these two broad goals, we developed data-centric project-based courses focusing on recent data analytics research at the University of Wisconsin-Parkside (*University A*), Kenosha, USA, and another focusing on industry collaboration at Thiagarajan College of Engineering, Madurai, India (*University B*). A graduate level course (MS – Computer and Information Systems (CIS)) in data science concentration and an undergraduate level course (B.Tech. Information Technology (IT)) in IT were selected for the pilot study at University A and B, respectively. Data collected from the two universities

TABLE I
DATA-CENTRIC COURSE DETAIL AT TWO INSTITUTIONS

University, Major &Semester	Course Name, Credits, Mode of Instruction	Innovative Course Outcomes	No. Students
UWP MSCIS Winterim 2022 (University A)	*Data Science and Machine Learning Project 3 credits- Hybrid	SLR and publishing research article on recent advances in data science and ML	10
TCE B.Tech IT VII Sem 2021 (University B)	*Data Science & AI Applications 2 credits - On-line	Establish Industry Collaboration – Buddi.AI and Internship and Industry job offers	48
			Total: 58

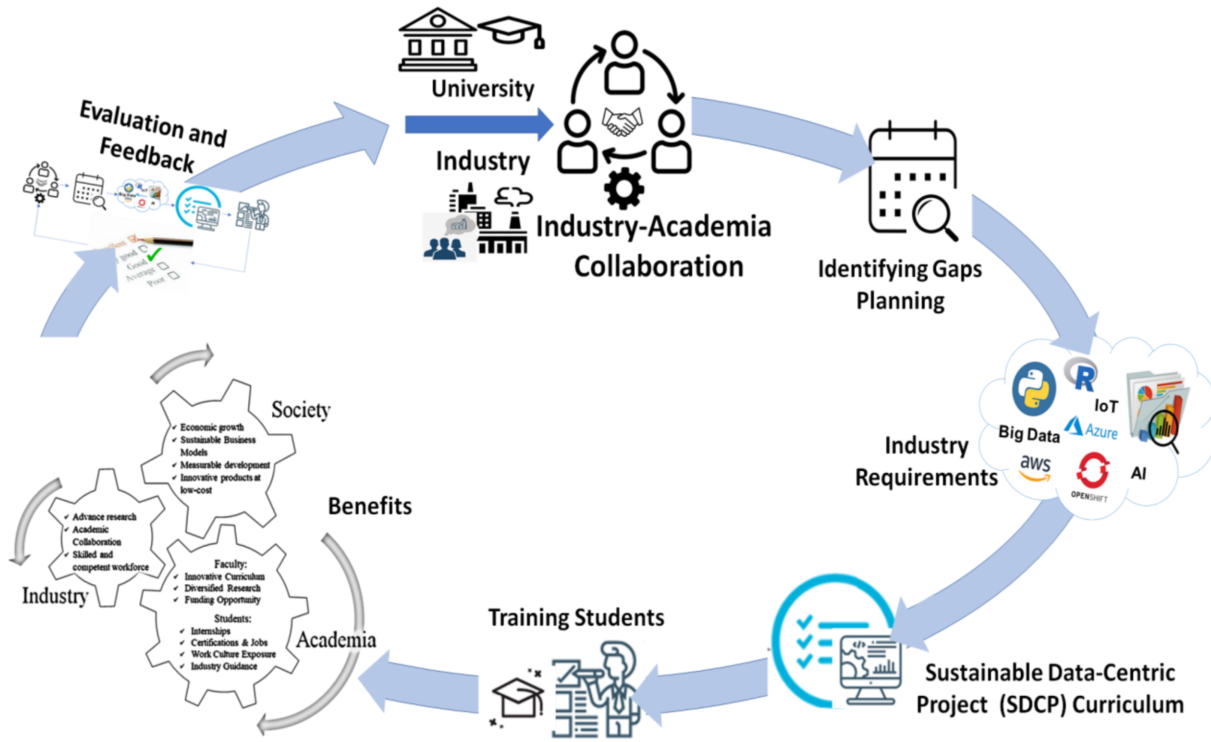

Fig. 2. Sustainable Data-Centric Project (SDCP) Curriculum Iterative Process Workflow.

describing the details of the courses are listed in Table I.

The details of the courses offered, and the course outcomes are discussed in the following subsections.

1) Data Science and Machine Learning Project course at University A

The "Data Science and Machine Learning Project" course offered at *University A* aims at reinforcing data science and ML concepts using industrial case study problems and data from different domains (e.g., healthcare, finance, supply chain management, and sports). The students were involved in team-based projects that involved an extensive Systematic Literature Review (SLR) on the topic and implementation of predictive models using data analytics and ML algorithms. The deliverable, along with the model, was research articles to be submitted to technical conferences.

The course goals and objectives are listed as follows:

"Data Science and Machine Learning Project course intend to prepare the students to embark on their journey as Data Scientist and Machine Learning Engineer. Students will select a research problem/topic from the Data Science and Machine Learning of their choice, perform a detailed and systematic literature review related to their topic, document their understanding, acquire data, perform data wrangling, analyze various machine learning models, and compare and evaluate them. Students will document and present their findings from all stages of their work. The final course product will be a paper edited using LaTeX, a software for technical typesetting documents. The final paper can be submitted to a peer-reviewed conference or a poster.

Upon completion of this course, the students will have a firm understanding of writing research articles in the Data Science and Machine Learning landscape and several types of relevant and most recent research concepts, implement, train, and apply machine learning models in various application domains, and understand the caveats of real-world data and settings."

The broad goals of the course deliverables that align with the University's Shared Learning Goals (bulleted and bold) are listed below:

- **Communication (C):** literacy, oral communication, creative expression - Communicate Information Systems effectively and professionally within the Enterprise: Students prepare and present business-oriented plans and reports, such as security plans and research papers.
- **Reasoned Judgment (RJ):** Critical thinking, ethical thinking, scientific thinking, analytic skills, aesthetic skills - Evaluate Technology: Students can read and assess professional and research papers on Information technology, information systems, or computer science subjects.
- **Social and Personal Responsibility (S&PR):** Teamwork, civic engagement, individual accountability, social equality, global perspective, Integrate IT and Business: Students can understand and integrate IT solutions into a business, including planning, communicating, and working with business professionals related to IT. Students also understand the ethical implications of their decisions.

The assessment criteria for the course based on these learning goals are presented in the course syllabus (Ramasamy, 2022).

2) Data Science & AI Applications at University B

University B offers industry-supported courses to provide substantial theoretical and practical foundations in Data Science and Artificial Intelligence. Among other objectives, the course aims to prepare students to work with different Python packages and libraries and increase their familiarity with them. A study has been conducted by *University B* to explore the possibility of collaborating with *IBM, CDAC, Zebra Technologies*, and *Symantec* in various domains, including Data analytics, mobile applications, cyber security, web applications, etc.

Following are the steps for initiating industrial credit courses are listed below.

a. Analyze the gaps between existing curriculum and industrial requirements
b. Gather feedback from current students and alumni
c. Collaborate with various industries and confirm the agreements
d. Secure approval from the department head, faculty dean, and principal
e. Offer the industry-supported one- or two-credit courses to students who obtained a CGPA above 8.0
f. For one-credit courses, Industrial Experts will address one weekend (14 hours), and for two-credit courses, Industrial Experts will handle both weekends (28 hours).
g. Industry experts will conduct the assessments based on the assignments and project submissions.

Department of Information Technology at *University B* collaborated with Buddi.AI (AI-based startup industry) and proposed a two-credit course (28 hours) on Data Science and AI Applications (Suganya, 2022). The course content is divided into five use cases: Language identification from text snippets, Automatic natural casing of text, Automatic model selection, prediction of machine failure, and Class imbalance learning. Six *Course Outcomes (COs)* are evaluated through challenging assignments and mini projects. These activities helped students to think in the higher order blooms level (Apply and Analyze) in real-time, handling datasets in various domains -health, agriculture, education, social media, etc., under the guidance of industry experts.

The broad goals of the course outcomes align with the relevant *Program Outcomes (POs)* and are listed below:

- **PO1:** Engineering Knowledge: Apply the knowledge of Mathematics, Science, engineering fundamentals, and an engineering specialization to solve complex engineering problems.
- **PO5:** Modern tool usage: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.
- **PO6:** Engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- **PO12:** Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

The assessment criteria for the course based on these learning goals are presented in the course syllabus (Suganya, 2022).

3) Discussion of Pilot Study Course Outcomes

The students and industry stakeholders well received the two courses offered under the *SDCP* curriculum initiative. Three research articles formatted in LaTeX based on SLR of the recent advances in data science curriculum resulted from the student projects at *University A*. These articles were published at a regional conference and received appreciation from the panel members (*MICS, 2022*). The outcome of the industry-supported course offered at *University B* resulted in internships and placements for six students in the AI-based industry as data engineers.

The excerpt from the student course surveys and the feedback gathered from industrial collaborators on the benefits of the *SDCP* course are listed below.

- Collaborating with institutions offers industries work-ready talent with specialized knowledge.
- Students at universities gain opportunities to work on state-of-the-art technologies under the guidance of industry experts.
- The *SDCP* course curriculum prepares students to provide solutions for various real-life and industrial problems.
- The course responses are impressive. It can strengthen industry-academic interaction by establishing industry-supported laboratories, offering one-credit courses/certifications to students, inviting industry experts to conferences, workshops, seminars, guest lectures, faculty training by industry personnel, implant training, industrial visits, and internship opportunities.

V. Conclusions and Future Work

This research work presents the need for an innovative curriculum change with the explosion of data in every domain to address current industry research and data analytics requirements. Using the pilot studies conducted at two universities, we gained important insights into the significance of student research and industry-academic collaborations. Study results confirm that data science courses provide students with hands-on experience to uplift their careers. Meanwhile, students learn, explore handling commercially licensed software, and gain opportunities to explore more real-time applications. The multi-fold benefits of the Sustainable Data-Centric Projects (*SDCP*) courses, besides enhancing data science skillsets are as follows. Industry-academia partnerships accelerate research and knowledge in current technologies and create skilled workers. While the industry gains skilled workers with expert knowledge (Data extraction, preprocessing, modeling, and visualization) and practical training (Big data & artificial intelligence), University students benefit from working on challenging problems and relevant technologies.

In a nutshell, the pilot studies revealed students' interest in pursuing advanced research and improving their capabilities to solve real-time problems. We conclude that academia must potentially investigate adding more industry-based curriculum courses. Furthermore, strong industry-academia collaboration focused on innovative ideas and research and development investment will be explored in the future to help increase research capacity and sustainable solutions.

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