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WIP: The Design of a Professional Development Program for Petroleum Engineering Educators Towards Integrating Data Analytics and Machine Learning into Petroleum Engineering Curriculum

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Dr. Olatunde Mosobalaje is a faculty member at the Petroleum Engineering Department of Covenant University, where he is currently promoting digital innovations in engineering education. He is a member of the American Society for Engineering Education (ASEE), and the Society of Petroleum Engineers (SPE). His commitment to knowledge transfer is unmistakable as it manifest in his ongoing projects aiming at enhancing petroleum engineering curriculum with digital and data analytics contents. In 2023, he was part of a team that designed and published a module on introducing Python coding to petroleum engineering undergraduates – an award-winning effort. Most recently, he played a significant role in a team that developed an integrated framework for the integration of data analytics and machine learning into the petroleum engineering curriculum. He recently founded and is coordinating the Petroleum Data Analytics Special Interest Group (PDA_SIG) of students and young professionals. In teaching, Dr. Mosobalaje adopts a balanced blend of analogical reasoning, concept visualization, field application and workflow coding as a pedagogy style. His research interest is in engineering education, as well as in the deployment of data analytics and machine learning tools to petroleum engineering applications. In a modest way, his research undertakings have produced content-assessment-pedagogy alignment of innovative curriculum ideas, and extended the functionality of some existing geostatistical routines. As a testimonial of his pursuit of excellence in teaching, he received the Dean's award as the best teacher in the department. He also received the Best Paper award in an international conference featuring over 100 authors from 17 countries, and a bronze medal in another. Notably, Dr. Mosobalaje is currently participating in the 2025 Spring Cohort of the prestigious 'Empowering-the-Teachers' (ETT) fellowship, at the Massachusetts Institute of Technology (MIT).

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Abstract

The petroleum industry is increasingly embracing digital transformation, enabled by data analytics, machine learning and other data-driven innovations. The proliferation of oilfield data as well as the availability of open-source data mining softwares is opening up career frontiers in petroleum data analytics and machine learning. However, petroleum engineering curricula in academic programs are not keeping pace with these oilfield operational advances, leaving graduates with skill-gaps and unprepared for emerging career opportunities. There is a growing advocacy for curriculum upgrades towards producing graduates combining data analytics skills with petroleum engineering domain knowledge. Recently, a framework for the desired curriculum integration of data analytics and machine learning has been published, but a roadmap for its implementation is yet to be outlined. As the first component of the roadmap, we design a professional development program aiming to empower petroleum engineering educators with knowledge, skills and resources needed to effectively integrate data analytics and machine learning into teaching practices.

This project views the proposed professional development program as an intervention program, and therefore adopts the Theory of Change as a theoretical framework. Specifically, a series of steps is articulated as the causal pathway leading to the desired program impact: industry-ready graduates. Starting with the stated impact, we mapped backward through outcomes (improved teaching practices), outputs (educators' knowledge and skills), activities (training workshops and mentorship) to inputs (need assessment and curriculum mapping). Key topics addressed include fundamentals and petroleum engineering applications of data analytics and machine learning; Python coding skills; field case-studies; curriculum design and integration strategies; teaching methods and assessment techniques. Recognizing the shortcomings of site-based one-shot or occasional programs, we adopt the online, on-going and intensive delivery approach. Also, the proposed professional development program is designed to be implemented in collaboration with industry professionals under the aegis of the Society of Petroleum Engineers, particularly, its Data Science and Engineering Analytics Technical Section. Additionally, the sustainability of this project is designed around the creation of a community of practice and a repository of shared resources.

It is anticipated that the deliverables of the proposed professional development program will bridge the gap between petroleum engineering academic programs and industry practice. We solicit feedback suggestions on the design presented in this paper.

Introduction

In the face of prevalent operational challenges and the energy transition, the petroleum industry strives to optimize production, improve efficiency, minimize cost, reduce carbon footprint. In pursuit of these strategic goals, the industry is increasingly embracing digital transformation across its value chain. The ongoing oilfield digital transformation is significantly fueled by data-driven innovations such as petroleum data analytics (PDA), machine learning (ML), and artificial intelligence (AI). Due to advances in data acquisition technologies, the oil and gas sector have become prolific in data generation and measurement. A credible report indicates that an average offshore platform generates about 2 TB/day of data [1]. Further still, the proliferation of open-source data mining softwares is encouraging the use of insights from data in critical business decisions: from sub-surface modelling through production optimization to investment management. Expectedly, a workforce skillful in data analytics technology is critical to the adoption and sustainability of the oilfield digital transformation. Career opportunities in PDA, ML and AI are emerging for graduate petroleum engineers, as a result of the ongoing oilfield digital transformation. AI and digitalization have been identified as major factors in meeting the demands of improved productivity confronting the emerging generation of petroleum engineers [2]. However, the petroleum engineering (PE) academic curriculum is not keeping pace with these oilfield operational advances, leaving PE graduates with skill-gaps and unprepared for emerging PDA and ML career opportunities. Recent studies and surveys have lent credence to the need for curriculum upgrades ensuring PE graduates acquire data analytics skills in addition to petroleum engineering domain knowledge [3 – 6]. Most recently, a comprehensive framework for a proposed PDA and ML course module has been published [7]. The framework includes a layout of learning outcomes: skills and competencies expected of students upon completion of the course. The learning outcomes are carefully mapped with authentic assessment rubrics with oilfield use-case examples. While the published framework is a step in the right direction, we consider the empowerment of PE educators that will drive this initiative as a necessary condition for the desired curriculum integration. The anticipated implementation of the framework will greatly benefit from a program that engages PE educators, first. Hence, we propose a professional development program aiming to empower petroleum engineering educators with knowledge, skills and resources needed to effectively integrate data analytics and machine learning into teaching practices. It is our hope that this training-the-trainer approach will fast-track progress students, and will ensure sustainability of the initiative. In this work-in-progress paper, we present our on-going design of the proposed professional development program.

Samuel [8] highlighted the mis-alignment between the current state of PE education and the restructured petroleum industry. The author specifically noted the missing link as the applied knowledge of Industrial 4.0 technologies such as machine learning, AI and edge computing. The vast potentials and opportunities in introducing application-driven data analytics modules to aid effective teaching of engineering courses has been investigated [9]. The impressive feedback from students in the reported investigation provides a strong motivation for the current project. The impact of such educational change on students depends on the professional development of the change agents – the educators. Dancy et al [10] provides valuable insights into models of professional development for educators. The authors presented the Faculty Online Learning Community (FOLC) model as an improvement over other models such as Develop and Disseminate (DD) and Faculty Learning Community (FLC). The FOLC model is built around the concepts of Community of Practice (CoP) - a learning community related to a domain of practice. In the FOLC model, program participants meet virtually thereby affording participation from multiple institutions. Recognizing the shortcomings of site-based one-shot or occasional programs, we adopt the FOLC model.

Program Design Framework: Theory of Change

In simplest terms, a Theory of Change (ToC) is a strategic logical framework that depicts the roadmap to reach a desired long-term goal [11]. It is commonly depicted graphically as a causal pathways of building blocks representing various elements of the ToC: from impact to pre-conditions. The design of a ToC begins with a stated ultimate goal (long-term) and maps backward through layers of medium- and short-term goals to the actions required to achieve the goals. Each layer of goals requires the preceding layer as an intervention (goals or actions) for its attainment. The ideology of ToC is similar to that of Backward Design – a curriculum design model [12]. A popular description of the basic structure and elements of a ToC is provided by Anderson [11]. However, over time, terminologies used in ToC have been varied and inconsistent. In our presentation (Figure 1), the following terms are defined thus [13]:

1. *Stakeholders group*: the targeted beneficiary of the desired change.
2. *Stakeholders need*: the identified benefit(s) currently eluding the stakeholders group.
3. *Impact*: the ultimate long-term end-result that will satisfy the stakeholders' need.
4. *Outcomes*: what needs to happen (in medium-term) to trigger the impact.
5. *Outputs*: the change that must happen (in the short-term) to trigger the stated outcomes.
6. *Activities*: actions that must be taken to achieve the stated outputs.
7. *Inputs*: resources needed to execute the activities
8. *Pre-conditions*: external factors that must be in place to achieve goals.

Applying the Theory of Change to the Professional Development Program

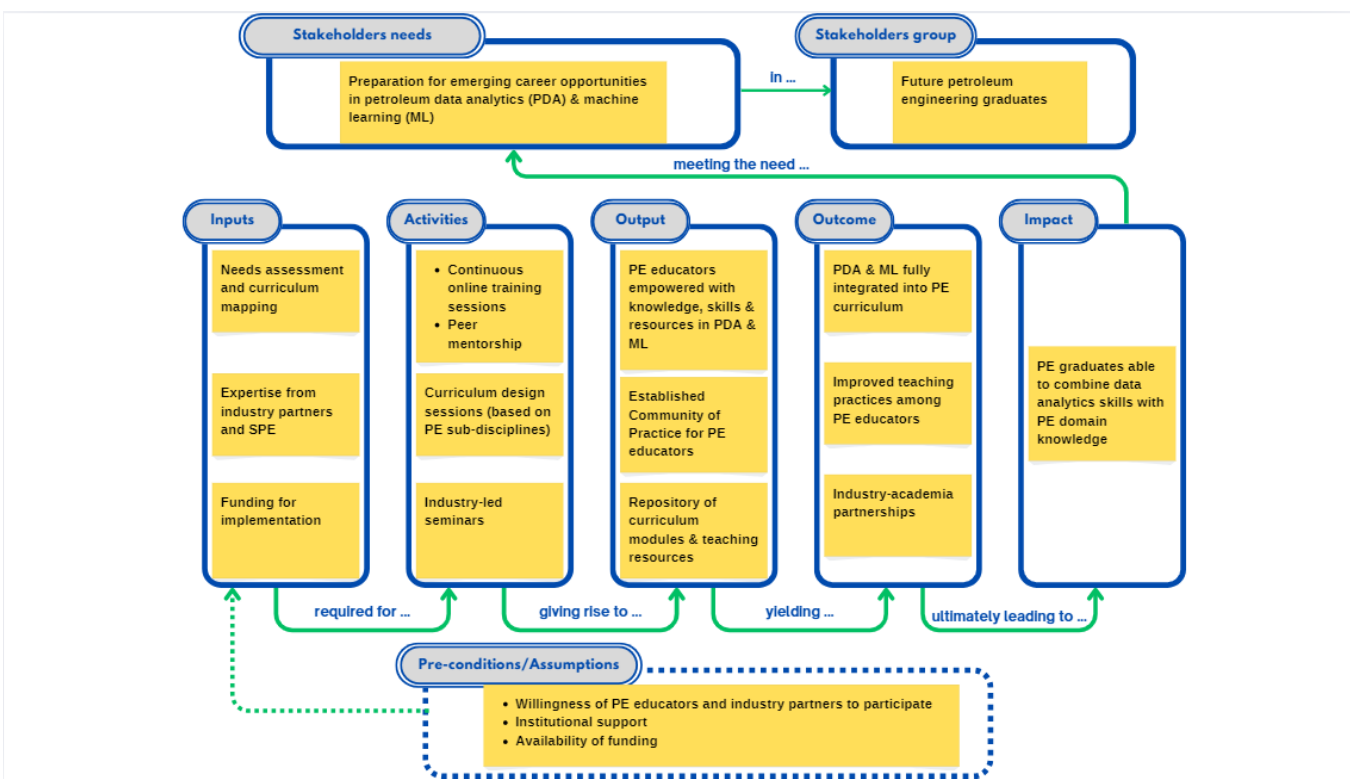

Figure 1: Theory of Change for the professional development program

Stakeholder Group and Needs

The professional development program primarily targets petroleum engineering educators, but its ultimate beneficiaries are the future petroleum engineering graduates (***Stakeholders' Group***). These future graduates need to be equipped with data analytics and machine learning (PDA & ML) expertise, for emerging career opportunities (***Stakeholders Needs***). These students face career challenges due to gaps in current curricula, necessitating a full integration of data analytics methodologies into petroleum engineering coursework.

Key *Impact and Outcomes*

The overarching impact of this initiative is to produce graduates capable of integrating PDA & ML skills with petroleum engineering domain knowledge for solving real-world oilfield problems. Achieving this impact relies on the following medium-term outcomes of the program:

- Complete curriculum integration of PDA & ML in petroleum engineering undergraduate programs.
- Hands-on demonstrations of PDA & ML use-cases during PE course modules instruction. Several examples of such use-cases, mapped with actual Python data science functionalities are presented by Mosobalaje et al. [7].
- Active mentorship and industry collaboration, providing internships, field experiences, and industry-led training.

Direct Outputs

The anticipated outcomes will emerge from the direct outputs of the professional development program:

- Empowered educators with PDA & ML expertise, trained to integrate these concepts into petroleum engineering curricula.
- A Community of Practice (CoP) where educators collaborate, share knowledge, and sustain ongoing learning.
- Development of shared resources, including teaching materials, Jupyter Notebooks, datasets, assessment tools, and catalogs of open-access learning materials.

Activities Outline

At the core of this initiative is a set of structured activities, including weekly virtual training sessions, already piloted to:

- Cover data analytics and machine learning fundamentals, petroleum engineering applications, Python coding, field case studies, and curriculum integration methods.
- Facilitate peer mentorship, allowing participants from varied backgrounds to collaborate and learn from each other.
- Organize breakout sessions for discipline-specific discussions on integrating PDA & ML into different petroleum engineering sub-fields.
- Host industry expert workshops, ensuring alignment with real-world applications.
- Enrolment in online courses.

Inputs & Implementation Considerations

The program's activities will be driven by key inputs, including:

- Needs assessment and curriculum mapping, leveraging surveys and published frameworks [7].
- Industry collaborations, facilitated through the Society of Petroleum Engineers' Data Science and Engineering Analytics Technical Section (SPE DSEATS).
- Resource planning, addressing funding needs for ICT infrastructure, travel, and conference participation.

Additionally, the program sustainability is ***pre-conditioned*** on external factors such as institutional support, participant commitment, and availability of funding.

An On-going Precursor Implementation

Recognizing that educators require foundational programming skills to effectively integrate data analytics and machine learning into petroleum engineering curricula, we initiated a pre-requisite professional development effort: the Python for Petroleum Engineering Educators – Community of Practice (PyPE_CoP) [14]. This initiative serves as a precursor to the proposed professional development program by equipping educators with essential skills in Python, widely recognized as the leading platform for ML and data analytics workflows. Early results indicate that participating educators are gaining confidence in integrating Python functionalities into their instructional practices, laying the groundwork for the next phase of training in PDA and ML. A preliminary survey conducted among *PyPE_CoP* 44 registered participants revealed that 56.8% and 38.6% rated themselves as ‘*novice’* and ‘*beginner*’ in Python programming, respectively. However, after 13 weeks of engagement, 53.8% of 13 respondents to a survey rated their Python programming skill as ‘*fairly improved*’ while 30.8% rated ‘*highly improved*’. A moderate 23.1% reported that they had incorporated Python programming into their teaching engagements. Conversely, the *PyPE_CoP* implementation has faced two notable challenges: participants availability and internet connectivity. Overall, the *PyPE_CoP* implementation has demonstrated the effectiveness of structured learning activities tailored for petroleum engineering educators. *PyPE_CoP* has adopted a blended learning approach, combining virtual training sessions, curated open-access resources, and peer mentorship, fostering engagement among educators across various institutions. These findings validate the need for targeted interventions that prepare educators for the next step—teaching data analytics and ML in petroleum engineering curricula.

Following the successful pilot implementation of *PyPE_CoP*, we plan to systematically transition from foundational Python programming training to specialized modules on petroleum data analytics and machine learning. The professional development program will leverage established engagement strategies from PyPE_CoP, including hands-on demonstrations, faculty mentoring, and collaborative curriculum alignment sessions. Additionally, empirical evaluation of PyPE_CoP’s effectiveness will provide insights into refining future training initiatives, ensuring sustained educators participation and industry relevance.

Future Implementation Directions

The professional development program will first be implemented as outlined in this paper, focusing on equipping petroleum engineering educators with data analytics and machine learning expertise. A rigorous empirical evaluation of the program's effectiveness is planned to assess its impact on:

- Teaching practices, measuring how educators integrate PDA & ML concepts into course modules.
- Students' learning outcomes, evaluating competency gains and practical application skills.
- Graduate employability, examining how participants' skill sets align with industry demands.
- Industry partnerships, tracking collaboration efforts and internship opportunities fostered by the initiative.

In order to ensure long-term sustainability, the Community of Practice will be actively maintained by engaging trained participants in mentoring and training future cohorts. Also, in order to facilitate knowledge dissemination, insights and lessons learned from the program will be shared through conference presentations and journal publications, ensuring broader academic and industry engagement. Upon successful implementation within petroleum engineering education, efforts will be made to scale up by adapting the framework for other engineering disciplines, creating a broader impact across technical fields that increasingly rely on data-driven methodologies.

Conclusion

The professional development program proposed in this paper represents a critical step toward aligning petroleum engineering education with the evolving demands of the industry. By prioritizing the training and upskilling of petroleum engineering educators, this initiative ensures that future graduates are not only prepared for emerging career opportunities but also equipped to drive innovation and operational efficiency in a rapidly transforming energy landscape. Empowering educators with data analytics and machine learning expertise will help bridge the gap between academic curricula and industry practice, fostering a workforce capable of leveraging data-driven insights to solve complex oilfield challenges. Recognizing that programming proficiency is foundational to this transition, we have already initiated an early-stage pilot—the Python for Petroleum Engineering Educators Community of Practice (PyPE_CoP)—to build essential coding skills among educators. Through sustained peer collaboration, faculty mentorship, and engagement with industry professionals, this program aims to foster a long-term, scalable impact on petroleum engineering education, ultimately producing graduates equipped to navigate the data-driven future of the energy sector.

Acknowledgement

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