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Enhancing ABET Summative Direct Assessment with AI and Blockchain: A Framework for Personalized Learning and Secure Evaluation

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Abstract

Accreditation Board for Engineering and Technology (ABET) emphasizes the achievement of specific measurable learning outcomes. However, conventional assessment methods often find it challenging to accurately capture the complexities of student learning and program effectiveness within the ABET framework. This study proposes a novel framework that enhances ABET summative direct assessment by integrating a carefully structured, weighted assessment system with the transformative potential of artificial intelligence (AI) and blockchain technologies. The framework leverages AI to personalize learning pathways, automate feedback generation, and drive data-driven curriculum improvement, while blockchain technology ensures secure data management, transparent grade recording, and verifiable student credentials. By grounding this integration in sound pedagogical principles and addressing ethical considerations, the proposed framework aims to create a more efficient, trustworthy, and learner-centric assessment experience that empowers both students and educators to achieve better learning outcomes. This study also describes the roadmap of the integration of AI and blockchain technologies with the ABET assessment framework which involves the examination of the practicality, efficiency, and impact of these technologies at different stages of the assessment process. Another contribution is to identify and recommend the most suitable AI and blockchain tools for effective implementation in ABET assessment. This involves a comparative analysis of available technologies, considering factors such as compatibility with ABET principles, data security, and the potential to enhance transparency, efficiency, and personalization in student assessments. We aim to reinforce the proposed approach by harnessing modern technologies in AI and advanced security measures to enhance the effectiveness, efficiency, and security of our proposed assessment framework.

Keywords: Large language model (LLMs), AI, student outcome assessment, ABET accreditation, assessment methodology, educational quality, blockchain

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INTRODUCTION

ABET accreditation, widely sought by computer engineering programs to enhance their quality and graduate attributes, necessitates a robust system for assessing student outcomes and implementing continuous improvement plans. A critical aspect of this process lies in selecting and implementing effective student outcome assessment (SOA) methodologies. However, institutions often face challenges in navigating the diverse approaches to SOA and aligning them with the principles of ABET requirements [1].

A recent study [1] investigated the SOA methodologies employed by seven ABET-accredited computer engineering programs, analyzing their self-assessment reports (SARs) to compare and contrast their approaches. The study highlighted the diverse methodologies used by successful programs, ranging from classical (extensive) models to lightweight (capstone project-based) models. It emphasized the importance of direct assessment methods to gather tangible evidence of student learning and the significant role of continuous improvement plans in driving program enhancement.

The study also revealed key challenges in implementing effective SOA for ABET accreditation, including:

1. *Balancing comprehensiveness with resource constraints:* Designing an assessment system that is both thorough and manageable within available resources.
2. *Selecting appropriate assessment methodologies:* Choosing suitable approaches for defining program educational objectives (PEOs), student outcomes (SOs), and performance indicators (PIs), as well as selecting direct and indirect assessment techniques and developing rubrics.
3. *Ensuring fairness and impartiality:* Implementing assessment methods that are unbiased and inclusive, catering to diverse stakeholder needs and contexts.
4. *Balancing faculty workload and promoting buy-in:* Engaging faculty members effectively while minimizing increased workload and resistance to new methods.
5. *Securing management support and resources:* Obtaining adequate funding and autonomy for assessment development and implementation.
6. *Measuring student performance against predetermined targets:* Aggregating and interpreting data from various assessment methods and scales to effectively gauge program effectiveness.

Building upon these findings, this study proposes a novel framework that enhances ABET summative direct assessment by integrating AI and blockchain technologies. By leveraging AI's capabilities in personalization, automation, and data analysis, and blockchain's strengths in security, transparency, and data integrity, we aim to address the identified challenges and create a more effective, efficient, and learner-centric assessment experience within the ABET framework.

RELATED WORKS

Several research efforts have focused on improving various aspects of academic accreditation, including:

1. *Documentation of ABET accreditation experiences:* Studies have analyzed ABET criteria, documented best practices, and guided the preparation of self-study reports [1–4].
2. *Program assessment:* Researchers have explored various assessment approaches for PEOs and SOs, investigated the use of data mining for predicting student outcomes, and proposed alternative assessment methods like rubric-based evaluation and discussion-based performance assignments [5–9].
3. *Remote ABET tools and methods:* The COVID-19 pandemic has spurred research on digital quality management systems, virtual accreditation processes, and online tools for data collection and reporting [10–14].
4. *Continuous improvement plans (CIPs):* Studies have proposed models for integrating ABET criteria with gamification theory, developed program enhancement plans, and advocated for faculty-driven continuous improvement processes [15–18].
5. *Outcome-based education (ABET):* Researchers have explored the impact of transitioning from traditional to ABET, proposed new curriculum designs, and investigated the role of assessment in driving learning transformation [19–22].

While these studies provide valuable insights into different facets of ABET accreditation and ABET, there is a gap in research exploring the practical and pedagogically sound integration of AI and blockchain technologies within ABET assessment frameworks, particularly for summative direct assessment. This study aims to address this gap by proposing a novel framework that leverages these technologies to enhance the effectiveness, efficiency, transparency, and personalization of ABET assessments, ultimately contributing to a more robust and learner-centric ABET experience.

TRADITIONAL DIRECT STUDENT ASSESSMENT METHOD

The traditional direct student assessment method comprises a systematic approach to evaluate and measure student learning outcomes in engineering programs. The steps involved in this method are as follows [16–18]:

1. *Defining program syllabus:* The first step involves defining the overall syllabus and curriculum of the engineering program. This entails outlining the content, objectives, and learning outcomes that students are expected to achieve throughout their academic journey.
2. *Defining course learning outcomes (CLOs) of each module:* Each module or course within the program is broken down into specific learning outcomes. These CLOs represent the measurable knowledge, skills, and competencies that students are expected to acquire upon completing each module.
3. *Defining performance indicators of each CLO:* For each Course Learning Outcome, specific performance indicators are defined to assess and quantify the level of achievement. Performance indicators provide clear criteria for evaluating student performance in relation to the desired outcomes.
4. *Linking CLOs of different modules to SOs:* The Course Learning Outcomes are aligned with the broader SOs that represent the overall educational objectives of the engineering program. This alignment ensures that the CLOs contribute to the attainment of the desired program-level outcomes.
5. *Determining the attainment level for the selected modules:* The attainment levels for each CLOs in the selected modules are determined based on the performance of students. These levels indicate the degree to which students have achieved the specified learning outcomes.
6. *Performing direct assessment on selected modules:* Direct assessment involves the evaluation of student work and performances in the selected modules. Faculty or evaluators review assessments such as exams, quizzes, homework, projects, and other relevant activities to gauge student achievement.
7. *Designing suitable rubric for the assessment process:* To ensure consistency and fairness in evaluating student work, suitable rubrics are designed. Rubrics provide clear and objective criteria for assessing the level of attainment of each CLOs.
8. *Using PIs to measure the attainment of each CLO:* The Performance Indicators defined for each Course Learning Outcome are utilized to measure the extent to which students have achieved the specified outcomes. These indicators provide quantitative data for assessment.
9. *Calculating student outcome achievement (SO%):* The overall Student Outcome achievement is calculated by summing up the attainment levels of all relevant CLOs in the selected modules and expressing it as a percentage. This computation provides a comprehensive measure of the students' overall achievement in attaining the desired SOs of the program.

While the traditional direct student assessment approach has been widely used for evaluating student learning outcomes, it is not without its limitations and challenges. Some of the problems with this approach include [19–20]:

1. *Resource-intensive:* The traditional direct assessment method can be resource-intensive, requiring significant time, effort, and personnel to implement effectively. Faculty members and administrators may find it burdensome to manage multiple assessment activities, especially in large academic programs.
2. *Limited assessment coverage:* Depending on the number of modules and courses within a program, it may not be feasible to assess every CLO in all modules. As a result, certain learning outcomes might receive more emphasis, while others may be overlooked, leading to an incomplete picture of students' overall learning.
3. *Assessment overemphasis on exams and quizzes:* Traditional direct assessment methods often rely heavily on exams and quizzes as assessment tools. While these are valuable evaluation

methods, they may not fully capture the range of skills and competencies developed through the entire learning process.
4. *Subjectivity in grading:* The assessment process involves human judgment and evaluation, which can introduce subjectivity and inconsistency in grading. Different faculty members may interpret rubrics differently, leading to variations in student assessments.
5. *Lack of timely feedback:* The traditional direct assessment method often involves time-consuming evaluation processes, leading to delayed feedback for students. This hinders their ability to identify areas for improvement promptly.
6. *Insufficient integration of technology:* While the proposed framework aims to leverage educational technology, the traditional direct assessment method may not fully embrace the potential of technological advancements to streamline data collection, analysis, and reporting.
7. *Cumbersome data management:* Handling and analyzing the data generated through direct assessment can become cumbersome, especially in large engineering programs with numerous modules and students.
8. *Focus on compliance rather than improvement:* In some cases, the primary focus of direct assessment might be on satisfying accreditation requirements rather than utilizing the assessment data to drive meaningful improvements in the educational program.
9. *Limited flexibility:* The traditional approach may lack the flexibility to adapt quickly to changes in curriculum, instructional methods, or emerging educational needs. This rigidity can hinder the incorporation of innovative teaching and learning practices.

Despite these challenges, the traditional direct assessment method has provided valuable insights into student learning outcomes and program effectiveness. However, to address these problems and enhance the assessment process, it is crucial to explore innovative approaches that promote a more lightweight, comprehensive, precise, and informative assessment framework, aligning with the proposed goals of this study.

RECOMMENDATIONS TOWARDS AI AND BLOCKCHAIN INTEGRATION WITH ABET SUMMATIVE ASSESSMENT METHOD

Artificial Intelligence (AI) refers to the ability of computer systems to perform tasks that typically require human intelligence, such as learning, problem-solving, and decision-making. AI encompasses a broad range of techniques and algorithms, including machine learning, natural language processing, and computer vision, enabling computers to analyze data, identify patterns, and make predictions or recommendations based on the information processed [22]. Blockchain technology, on the other hand, is a decentralized, distributed ledger that securely records and verifies transactions in a transparent and tamper-proof manner. Information is stored in blocks linked together in a chronological chain, with each block cryptographically secured and distributed across a network of computers. This decentralized structure eliminates the need for a central authority and ensures data integrity, making it resistant to manipulation or unauthorized access [23].

Integrating technology into the proposed ABET summative assessment framework can be facilitated by specific features of generative AI and blockchain, focusing on extracting meaningful features from student work. Generative AI's Natural Language Processing (NLP) can extract key features from student responses, like keywords or sentiment, to analyze understanding of concepts or identify areas of difficulty. Machine learning (ML) can learn from past assessments to identify features in questions or responses that predict performance on specific learning outcomes, ultimately improving the assessment's accuracy [22]. Blockchain's immutability ensures the authenticity and integrity of these extracted features, guaranteeing they have not been tampered with for fair and reliable assessment. Decentralization on permissioned blockchains allows a consortium of trusted institutions to securely manage access to feature extraction tools or models, providing transparency in data handling. However, careful selection of features to extract is crucial, and the explainability of the AI models' results is essential for instructor understanding. Additionally, robust data security measures are necessary throughout the extraction process to protect student privacy. By combining these features, technology integration can create a more efficient and effective assessment system that extracts valuable insights from student work for a data-driven approach to ABET assessment [21].

This section describes the roadmap for the integration of AI and blockchain technologies with the ABET assessment framework which involves the examination of the practicality, efficiency, and impact of these technologies at different stages of the assessment process. Another contribution is to identify and recommend the most suitable AI and blockchain tools for effective implementation in ABET assessment. This involves a comparative analysis of available technologies, considering factors such as compatibility with ABET principles, data security, and the potential to enhance transparency, efficiency, and personalization in student assessments. We aim to reinforce the proposed approach by harnessing modern technologies in artificial intelligence and advanced security measures to enhance the effectiveness, efficiency, and security of our proposed assessment framework.

Technology Integration Steps

The deployment of AI for assessment purposes involves the utilization of ML algorithms, NLP techniques, and data analytics to automate grading, generate personalized feedback, and derive actionable insights from assessment data. By leveraging AI, educators can streamline assessment workflows, reduce administrative burdens, and provide timely interventions to support student learning [15]. NLP and ML can analyze student responses in essays or short answer questions, identify patterns in performance across assessments, and even detect areas of difficulty. Supervised and Unsupervised Learning algorithms can leverage past assessment data to improve the system over time, identify trends, adjust assessment formats, predict student performance, and suggest personalized learning recommendations based on weaknesses. Natural language generation (NLG) and recommendation systems can further personalize the experience by suggesting additional resources or tailoring learning materials for students. Text summarization can provide instructors with concise summaries of key points from student work and assessment data, highlighting strengths and weaknesses. Finally, ML and robotic process automation (RPA) can automate tasks like grading certain question types, generating feedback based on responses, and streamlining administrative tasks associated with assessments. Overall, AI offers a powerful toolkit for analyzing data, personalizing learning, and streamlining the ABET assessment process [22].

Similarly, blockchain technology offers a decentralized and immutable ledger for securely recording assessment data, ensuring transparency, integrity, and trust in the evaluation process. Smart contracts embedded within the blockchain facilitate automated verification of credentials and enable seamless transfer of ownership of digital assets, such as certificates or credentials. Additionally, learning analytic models provide educators with valuable insights into student learning behaviors, preferences, and performance trends, enabling data-driven decision-making and personalized instructional strategies [21–23].

AI, with its computational prowess and data analysis capabilities, can revolutionize the assessment process by [22]:

- Automating routine tasks, freeing up faculty time and resources for personalized feedback and deeper learning experiences.
- Personalizing assessments by adapting to individual student learning styles and needs, offering a more nuanced understanding of student mastery.
- Providing real-time feedback through AI-powered tutors and automated analysis, enabling students to address knowledge gaps promptly.
- Analyzing vast amounts of assessment data to identify trends, predict potential challenges, and inform data-driven curriculum improvements.

On the other hand, blockchain, with its secure and transparent data storage capabilities, can address concerns related to [21]:

- *Data security and integrity:* Storing assessment data on a blockchain ensures tamper-proof records and protects student privacy.
- *Collaboration and sharing:* Securely share anonymized assessment data with other institutions for benchmarking and collaborative improvement.
- *Auditability and traceability:* Maintain a transparent record of historical assessment decisions and data changes, ensuring accountability and trust.
- *Streamlined data management:* Automate data verification and validation, reducing manual processes and potential errors.

While AI tools can significantly assist with each phase of the proposed assessment framework, it is important to understand that no phase will be fully automated. AI tools serve as a powerful tool for analysis, suggestion, and automation, but ultimately, the professional judgment and expertise of the program administrators remain crucial for decision-making. Table 1 lists a breakdown of the manual and automated aspects of each assessment phase of the enhanced ABET assessment:

Table 1 outlines the division of tasks between human program administrators and AI-assisted automation in the context of an Outcome-Based Education (ABET) assessment process. It highlights several key points:

- *All phases involve both manual and automatic tasks:* No phase is entirely automated, and human expertise remains crucial for decision-making, interpreting data context, and providing feedback.
- *Curriculum preparation and examination strategy requires the most human involvement:* Defining program goals, selecting content, creating rubrics, and providing feedback are complex tasks requiring human judgment.
- *Student outcome calculation and reporting offer the highest automation potential:* AI can handle calculations, generate reports and visualizations, and even predict potential challenges.
- *AI can offer valuable support across most phases:* While final decisions and interpreting context remain human responsibilities, AI can analyze data, suggest adjustments, and automate tasks, streamlining the assessment process.

The specific number of manuals vs. automated tasks varies by phase, with some phases having a more balanced distribution. However, Table 1 effectively demonstrates how AI can augment human expertise, leading to a more efficient and data-driven ABET assessment process.

Table 2 explores the potential benefits and roles of blockchain technology in the various phases of an ABET assessment process. Across several phases (CLO weighting, examination strategy, variable attainment levels), blockchain offers significant benefits by fostering transparency and security. It creates a tamper-proof record of data and decisions, allowing for better auditability and preventing unauthorized changes. This can be particularly valuable for stakeholders who need to trust the assessment process. Also, Table 2 emphasizes the role of blockchain in ensuring data integrity and trust within the assessment process. By automating data verification and validation (student outcome calculation and reporting), blockchain can minimize errors and increase confidence in the calculated results. Additionally, secure data sharing with other institutions becomes possible while protecting student privacy. While Table 3 outlines potential benefits, it is important to consider the specific functionalities and feasibility of blockchain implementation in each phase. This will depend on the chosen platform, technical details, and integration with existing systems. Further exploration is needed to understand the development and maintenance costs associated with implementing blockchain solutions within ABET assessment.

Recommended Platforms

Selecting the appropriate AI and blockchain tools for implementation in ABET assessment requires a thoughtful and strategic approach. Firstly, it is essential to assess the specific needs and objectives of the educational institution, considering factors such as the scale of implementation, existing technological infrastructure, and the desired level of automation. A thorough evaluation of available AI and blockchain solutions is crucial, focusing on their compatibility with the ABET framework and their ability to enhance transparency, efficiency, and personalization in student assessment.

Table 1. AI manual and automatic aspects for assessment phases.

Phase	Manual aspects (requires program administrator expertise)	Automated aspects (assisted by AI)
Curriculum Preparation	1. Defining program goals and learning outcomes. 2. Selecting and describing content and activities. 3. Deciding on assessment methods and rubrics. 4. Collaborating with other instructors. **(4 Tasks)**	1. Analyzing existing materials to identify relationships and gaps. 2. Suggesting personalized learning paths for students. 3. Generating content ideas and resources aligned with program objectives. 4. Facilitating communication and collaboration among instructors. **(4 Tasks)**
CLO weighting	1. Interpreting data and its implications for weighing decisions. 2. Justifying adjustments to CLO weights to students and stakeholders. 3. Making final decisions considering factors beyond data (e.g., program priorities). **(3 Tasks)**	1. Analyzing student performance data to identify CLOs where students struggle or excel. 2. Suggesting potential adjustments to CLO weights based on data and pedagogical considerations. 3. Tracking historical CLO weight changes and justifications. **(3 Tasks)**
Examination Strategy	1. Developing high-quality and aligned exam questions. 2. Creating clear and consistent rubrics for fair and reliable assessment. 3. Grading exams, especially open-ended responses. 4. Providing meaningful and personalized feedback to students. **(4 Tasks)**	1. Personalizing exam questions based on individual student data (strengths and weaknesses). 2. Adapting exam difficulty dynamically based on real-time student performance. **(2 Tasks)**
Variable Attainment Levels	1. Defining the unique purpose and importance of each module type. 2. Setting appropriate attainment levels for each module type, balancing rigor, and feasibility. 3. Monitoring student performance and interpreting trends for potential adjustments. 4. Communicating attainment levels and expectations to students. **(4 Tasks)**	1. Recommending adjustments to attainment levels based on student data and learning styles. 2. Adapting attainment levels dynamically for individual students based on real-time performance. 3. Analyzing historical data on attainment levels across cohorts to identify improvement areas. **(3 Tasks)**
Student Outcome Calculation and Reporting	1. Collecting and analyzing student performance data beyond just calculations. 2. Interpreting data and identifying areas for improvement based on the understanding of the context. 3. Generating reports tailored to the audience and ensuring clarity and meaningfulness. 4. Effectively communicating findings and implications to stakeholders. **(4 Tasks)**	1. Automating all mathematical calculations involved in SO% determination. 2. Generating interactive dashboards and visualizations for easier data exploration and identification of trends. 3. Predicting potential challenges in achieving SO% targets based on data analysis. **(3 Tasks)**

Table 2. Benefits and roles of blockchain in ABET assessment processes.

Phase	Roles of blockchain	Benefits of blockchain
Curriculum Preparation	*Not applicable:* Blockchain does not directly contribute to curriculum development.	*Not applicable:* Blockchain itself does not create or manage curriculum content.
CLO weighting	*Auditable history:* Provides a clear and verifiable record of past CLO weighting decisions, aiding in future adjustments and analysis.	*Transparency and immutability:* Securely stores historical CLO weight changes and justifications, preventing unauthorized modifications and ensuring transparency for stakeholders.
Examination Strategy	*Improved accountability:* Ensures data integrity and prevents unauthorized access or modification of exam materials and student responses.	*Enhanced security:* Secures exam delivery and student response storage with tamper-proof encryption and decentralized verification, minimizing the risk of data breaches and manipulation.
Variable Attainment Levels	*Cross-institutional comparison:* Facilitates secure and transparent sharing of anonymized attainment level data with other institutions for benchmarking and collaborative improvement.	*Secure storage:* Securely stores historical attainment levels for different modules and student cohorts, enabling secure access and analysis.
Student Outcome Calculation and Reporting	*Secure data sharing:* Enables secure sharing of anonymized SO% data with other institutions for collaborative improvement while protecting student privacy.	*Data integrity and trust:* Automates the verification and validation of data used in SO% calculations, ensuring data accuracy and trustworthiness.

Table 3. Features of different blockchain platforms.

Blockchain platform	Pros	Cons
Ethereum	• Widely adopted, well-established ecosystem. • Strong community support and development resources. • Smart contract capabilities for automating assessment processes. • Support for decentralized applications (dApps).	• Scalability limitations (may be addressed in future upgrades) • Relatively high transaction costs.
Hyperledger Fabric	• Permissioned blockchain designed for enterprise use cases. • Customizable governance and privacy features. • Scalable architecture for handling large-scale assessment data. • Good performance and throughput.	• Less decentralized compared to public blockchains. • May require more setup and maintenance.
Quorum	• Ethereum-based, enterprise-focused blockchain. • Enhanced privacy features for sensitive student data. • High transaction throughput. • Compatibility with Ethereum tools and standards.	• Still under development, the evolving ecosystem • Potential vendor lock-in.
Corda	• Designed for regulated industries, strong focus on security and privacy. • Notarization capabilities for verifying assessment records. • Interoperability with other Corda networks.	• Limited use cases outside of financial services • Smaller developer community.
Polygon	• Layer-2 scaling solution for Ethereum, addressing scalability and cost issues. • Faster transaction speeds and lower fees. • Compatibility with Ethereum dApps and tools.	• Adds complexity to the overall architecture. • Still under development, potential risks.

Starting with blockchain, some platforms could be suitable for the application of enhancing student assessment in ABET [21] (Table 3).

While the proposed enhanced assessment method boasts a lightweight, comprehensive, precise, and informative approach to student evaluation, integrating Ethereum blockchain technology can further elevate its pedagogical value. Ethereum's well-established ecosystem offers abundant resources and developer tools, streamlining the development process for this integration. Even though Ethereum might have scalability limitations, it excels in fostering transparency. Students can track their progress in achieving learning outcomes through final exam performance and verify the integrity of their assessment records on the blockchain. This transparency builds trust in the system and aligns with the pedagogical aim of clear communication between instructors and students. Beyond streamlining the assessment process through automated tasks and secure data storage, Ethereum can support a comprehensive and data-driven approach. The immutable nature of blockchain ensures the accuracy and security of data related to learning outcomes achievement for all modules.

This data provides a holistic view and fosters alignment with program objectives, becoming a valuable resource for future analysis of curriculum effectiveness. While scalability might be a future consideration depending on program size, Ethereum's robust development ecosystem and transparency features make it a strong choice for this application. Integrating Ethereum blockchain technology can significantly enhance the pedagogical value of the proposed assessment method by streamlining processes, ensuring data security and integrity, and providing a platform for continuous improvement within the program.

Setting up the Ethereum blockchain directly connects to the ABET assessment framework. It aligns with technology integration by requiring platform selection (e.g., Ethereum), designing a data model for storing assessment data (learning outcomes, performance, feedback), and implementing security measures. Additionally, Ethereum's features address aspects considered when analyzing the assessment method. Its immutability guarantees the trustworthiness of data used to analyze effectiveness, and transparency allows students to track progress on learning outcomes, potentially verifying assessment records. Pedagogically, balancing security with student privacy through anonymization techniques is crucial. The proposed assessment method should be compatible with blockchain data storage, and clear communication regarding integration and data usage is necessary for both students and instructors. Overall, the Ethereum blockchain offers enhanced security, transparency, and potential for streamlined data analysis within the ABET framework, but careful consideration of pedagogy, privacy, and integration transparency is essential.

To clarify the technical efforts needed for setting up Ethereum to secure student assessment in ABET, several key steps are required [21], as shown in Figure 1:

1. Network selection: We recommend using the "Mainnet" for large-scale deployments due to its high security and transparency, despite potentially high transaction costs. Starting with "Testnet" is advisable for initial testing and development, offering lower fees and faster transactions.
2. Smart *contract development*: Smart contracts need to be developed to automate essential assessment processes such as recording CLO weights, calculating student outcomes, and managing data access. Solidity, along with relevant libraries for functionalities like tokenization and data storage, can be adopted for smart contract development.
3. Wallet *integration*: Implementation of wallets for students and institutions to manage Ethereum holdings and interact with smart contracts. Options such as MetaMask, MyEtherWallet, or custom wallet solutions tailored to specific needs should be considered.
4. Data storage and *management:* Deciding whether to store assessment data (e.g., CLO definitions, student performance) on-chain or off-chain. Decentralized storage solutions like IPFS or Filecoin should be considered for tamper-proof data preservation.

5. Security and *privacy:* Implementing robust security measures to protect against hacks and data breaches, including the use of multi-signature wallets and secure smart contract coding practices.
6. Front-*end development:* Developing a user interface (UI) for students and instructors to interact with the system, view assessment data, and manage their participation. This may involve building web applications or integrating with existing learning management systems (LMS).
7. Deployment and *testing:* Deploying smart contracts and UI to the chosen Ethereum network and conducting thorough testing to ensure smooth operation and accurate data handling.

Returning to AI technical advancements, the integration of Large Language Models (LLMs) such as Gemini and ChatGPT presents exciting possibilities for ABET assessments. Table 4 compares the strengths and weaknesses of both LLMs, highlighting their potential to revolutionize student learning assessment within the context of ABET [22].

While both ChatGPT and Gemini offer possibilities for the proposed ABET summative assessment system, their strengths cater to different areas. ChatGPT's adaptability allows for potentially creative assessment formats, but it is factual errors and limited explainability raise concerns. Conversely, Gemini's focus on knowledge integration aligns with ABET's learning outcome focus, and its informative feedback aligns with assessment best practices.

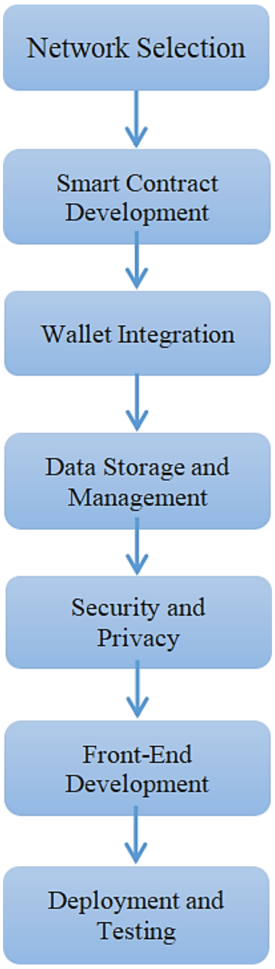

Figure 1. Setting up Ethereum to enhance student assessment in ABET.

Table 4. Comparison between ChatGPT and Gemini.

Feature	ChatGPT (OpenAI)	Gemini (Google)
Area of Focus	Creative text formats (all types - potential)	Open-ended, analytical, creative
Strengths for ABET	Adaptable (various tasks), potential for creative assessments	Knowledge integration (aligns with ABET's learning outcome focus), adaptable
Weaknesses for ABET	Prone to factual errors and bias, limited explainability	New and evolving (requires further research in assessment)
Data Security and Privacy	Unclear	Strict protocols (Google)
Feedback Style	Limited	Informative, highlights strengths/weaknesses
Explainability and Transparency	Low	Emerging

However, Gemini, being under development, needs further research in assessment applications. Security-wise, Gemini's strict protocols are reassuring, while information on ChatGPT's data practices is unclear. From the above table, Gemini can be considered as a powerful AI tool to enhance various aspects of the system due to the following reasons [22]:

1. *Personalization and adaptation:* Gemini can analyze the program syllabus and suggest improvements based on student needs, learning styles, and past performance data. This can lead to a more personalized and effective learning experience. Gemini can also analyze student progress and adjust the weights of CLOs on the fly. This ensures that students focus on areas where they need the most help and maximizes their learning outcomes. Based on individual student performance and preferences, Gemini can recommend personalized learning pathways, suggesting relevant resources, exercises, and study materials. This fosters a more engaging and efficient learning experience.
2. *Assessment and feedback:* Gemini can analyze student work using NLP to provide automated grading and personalized feedback. This saves instructors time and allows for more immediate and helpful feedback for students. Gemini can also develop intelligent assessment tools that go beyond traditional multiple-choice questions. These tools can involve open-ended questions, simulations, and real-world problem-solving tasks, providing a more holistic evaluation of student learning. On the other hand, Gemini can analyze student data to predict potential learning challenges and recommend interventions before they occur. This proactive approach can help prevent students from falling behind and ensure they stay on track for success.
3. *Data-driven insights and decision-making:* Gemini AI can analyze large amounts of assessment data to identify trends, patterns, and areas for improvement in the program. This data-driven approach can inform curriculum development, teaching methods, and overall program effectiveness. Based on individual student performance and overall program data, Gemini can provide personalized recommendations for instructors to tailor their teaching approaches and support specific student needs. Gemini can continuously analyze data and feedback to identify opportunities for improvement within the assessment system itself. This ensures that the system remains effective and adapts to changing needs over time.

There are three primary technical approaches for integrating Large language model (LLMs) (such as Gemini) with ABET assessment systems: pre-built integration, API integration, and custom development [23]:

1. Pre-built integrations offer a user-friendly and efficient solution when readily available from the chosen ABET platform. They often require minimal technical expertise and streamline the setup process. Pre-built integrations can provide a basic level of LLM support, such as automated grading of simple questions or basic feedback generation. However, their limited customization might not fully address the specific learning outcomes or assessment formats used in the ABET system.

2. Application Programming Interface (API) integration provides more flexibility by allowing developers to directly interact with the LLM's API. This approach requires a development team with expertise in both the platform's technology and the LLM's API structure. Careful attention must be paid to secure data transfer protocols and proper authentication mechanisms. APIs offer greater flexibility to tailor the LLM's role in the assessment. Educators can leverage specific functionalities to create more sophisticated assessments, analyze student responses for deeper insights aligned with learning outcomes, and potentially personalize feedback based on identified strengths and weaknesses.
3. Custom development, while resource-intensive, offers the highest level of control and customization. This approach is ideal for complex use cases with specific needs, particularly when pre-built integrations or API options are unavailable. A dedicated development team with expertise in both the ABET platform and the LLM can design and build a custom solution that seamlessly integrates the LLM's functionalities within the assessment system. Custom development offers the potential to fully integrate the LLM into the assessment process, maximizing its pedagogical value. Educators can design assessments that leverage the LLM's strengths in areas like personalized question generation, in-depth feedback analysis aligned with learning outcomes, and potentially adaptive assessments that adjust based on student performance.

The choice of integration approach will depend on the specific needs of the educational institution, available resources, and the desired level of control over the LLM's role within the assessment process. Regardless of the chosen method, security and data privacy must be paramount considerations throughout the integration process. Additionally, educators should be informed about the LLM's role within the assessment system and receive proper training on effectively utilizing LLM feedback to enhance student learning outcomes.

Technology Integration Issues

The technology solutions proposed in this study aim to modify student assessment in ABET in different aspects:

1. *Enhanced effectiveness and efficiency:* Streamlining assessment processes and leveraging technology can free up valuable faculty time and resources, allowing for more personalized learning experiences.
2. *Improved transparency and trust:* Blockchain technology's inherent security and immutability can foster greater trust in the assessment process, benefiting both students and educators.
3. *Personalized learning and targeted interventions:* AI-powered insights into student performance can enable tailored learning pathways and timely interventions for struggling students, promoting improved outcomes.
4. *Continuous program improvement:* Data-driven insights from the assessment process can inform continuous program improvement, ensuring alignment with evolving industry demands and student needs.

On the other hand, it is crucial to acknowledge the inherent limitations of the proposed solutions:

1. *Technological immaturity:* AI and blockchain technologies, though promising, are still evolving. Scalability, cost-effectiveness, and interoperability with existing systems might pose challenges during implementation.
2. *Data privacy and security:* Balancing the benefits of data sharing with the need to protect student privacy requires careful consideration and ethical implementation strategies.
3. *Faculty training and adaptation:* Successfully integrating these technologies necessitates faculty training and support to adapt their assessment practices and utilize the generated insights effectively.
4. *Resource requirements:* Implementing and maintaining these technologies might require additional resources, necessitating careful planning and budgetary considerations.

Finally, it is important to emphasize that the proposed assessment approach does not advocate for handing over critical decisions entirely to AI. Instead, AI is considered a valuable tool to augment human expertise, particularly in tasks such as automated grading, personalized learning feedback, and data-driven analysis. However, the importance of human oversight and verification in all key stages of the assessment process is still recognized. To ensure accuracy and reliability, the following safeguards are proposed:

- *Human review of AI-generated assessments:* Experts will review and potentially adjust AI-generated assessments to ensure alignment with learning objectives and mitigate potential biases.
- *Transparent and explainable AI models:* The utilized AI models must be transparent and explainable, allowing educators to understand how assessments are made and identify any potential issues.
- *Ongoing monitoring and evaluation:* Administrators must continuously monitor and evaluate the performance of the AI tools, making adjustments as needed to ensure their effectiveness and fairness.

CONCLUSIONS

This study presents a novel framework for enhancing ABET summative direct assessment by integrating AI and blockchain technologies, addressing the limitations of traditional assessment methods, and promoting a more learner-centric approach. Recognizing the challenges in balancing comprehensiveness with resource constraints, selecting appropriate assessment methodologies, ensuring fairness, and effectively engaging faculty, we propose a framework that leverages AI and blockchain to streamline processes, personalize learning, and enhance the security and transparency of assessment data.

AI plays a crucial role in personalizing learning pathways by analyzing student performance data and identifying areas for improvement. AI-powered tools provide automated, personalized feedback, guiding students towards mastery of essential concepts. Furthermore, AI facilitates data-driven curriculum improvements by analyzing aggregate performance data, revealing trends in learning outcome achievement, and informing revisions to teaching strategies and content. Blockchain technology strengthens the framework by creating a tamper-proof and auditable record of all assessment data, ensuring integrity, and promoting trust among stakeholders. Verifiable digital credentials, stored on the blockchain, provide irrefutable proof of student achievements.

While acknowledging the potential challenges associated with technology integration, such as data privacy concerns, faculty training needs, and the evolving maturity of AI and blockchain technologies, we advocate for a careful and ethical implementation approach. By emphasizing transparency in the use of AI tools, implementing robust data governance policies, providing adequate faculty training and support, and ensuring equitable access to technology, we can mitigate these challenges and maximize the benefits of these transformative technologies.

The proposed framework not only streamlines and secures the ABET assessment process but also creates a more personalized, data-driven, and accountable learning environment. By fostering a culture of continuous improvement and empowering both students and educators with advanced technological tools, we can create a more effective and impactful experience that equips graduates with the knowledge and skills necessary to thrive in the modern workforce. Further research and practical implementations are needed to explore the full potential of this framework and refine its application within diverse educational contexts.

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