Empowering Engineering Students: Blockchain Learning Tokens for Assessing ABET Student Outcomes and Enhancing Quality Control in Innovation-Based Education

Isaac Heizelman, University of North Dakota

Isaac Heizelman is a senior undergraduate engineering student at the university of north of Dakota.

Nicholas M. Bittner, University of North Dakota

Nick is currently a Biomedical engineering student at the University of North Dakota since graduating with a associates in engineering from Cankdeska Cikana Community College located on the Spirit Lake nation. Utilizing the innovation based learning model found in his new department, he is spear heading an effort connect the Tribal colleges and Universities to forge long lasting and productive relationships.

Mr. Enrique Alvarez Vazquez, North Dakota State University

Enrique is an experienced Systems Engineer with a demonstrated history of working in the electrical and electronic manufacturing field. Highly skilled in Embedded Devices, Software Engineering, and Electronics. He is a strong information technology profes

Dr. Dan Ewert, University of North Dakota

Dr. Ewert has been involved in cardiovascular engineering for over 30 years in research and instruction. His research includes space physiology, high-gravity physiology, medical device design, leadless pacing, and radiofrequency effects on gene expression. He has a keen interest in new educational models especially in the area of innovation, experiential learning, and project-based learning. He currently serves as program director for the University of North Dakota's Biomedical Engineering program and is actively developing an Innovation Based Learning methodology.

Ryan Striker, University of North Dakota

Ryan Striker is a life-long learner. Ryan has two decades of professional experience designing embedded electronic hardware for industrial, military, medical, and automotive applications. Ryan earned his BS and PhD in Electrical Engineering and his MS in Systems Engineering. He now teaches Biomedical Engineering at the University of North Dakota using a methodology known as Innovation-Based Learning.

Abstract:

This paper explores the implementation of a self-audit form to assess the attainment of ABET (Accreditation Board for Engineering and Technology) student outcomes from the unique vantage point of both students and the instructional team. The study is situated within the context of innovation-based learning, a paradigm where students actively engage in engineering projects throughout their undergraduate journey. These innovation projects foster a safe to fail environment where failure is accepted in the form of a provable good faith effort. This enables students to derive invaluable insights from their missteps But gives them a launching pad to do projects where a positive outcome isn't necessarily guaranteed, traditionally known as a moonshot, were high risks can land high rewards This approach empowers students to grasp fundamental engineering principles and apply them in their innovation projects to leverage their education to jumpstart their future careers.

A distinctive feature of this learning ecosystem is the custom learning management system, MOOCIBL, which rewards students with learning tokens. As participants in our Biomedical Engineering program, students amass blockchain-based learning tokens across their undergraduate courses. This research introduces the innovative concept of using these tokens as an analytical tool for quality control. To investigate the impact of learning tokens on the assessment of ABET student outcomes, students were tasked with classifying their tokens into general and program criteria student outcomes. At the commencement of the semester, students were prompted to self-assess their progress in achieving student outcomes for years 1-3 of their undergraduate education, initially providing a percentage of their attainment. Subsequently, they categorized their tokens and adjusted their free learning experiences to address identified gaps. At the semester's conclusion, students reassessed the completeness of their attainment, with instructor validation of token classifications.

The results of this study were analyzed, incorporating student and instructor perspectives. Interviews were conducted to gain insights into the participants' experiences with this novel approach. The research demonstrates that the combination of an ABET student outcome template and blockchain learning tokens can serve as a powerful tool to enhance quality control and empower students in higher education by granting them greater autonomy over their own learning journeys. This innovative approach offers a promising avenue for advancing engineering education and fostering student ownership of their learning outcomes.

Keywords:

Innovation-Based Learning, ABET, MOOCIBL, blockchain, education, engineering

Introduction:

Engineering education has been shifting away from traditional modes of teaching involving high-stakes testing and quizzes. A new mode of engineering education having success recently is innovation-based learning (IBL). The dynamic educational structure of IBL allows students to learn core fundamental principles of engineering guided by ABET student outcomes while also engaging in semester-long innovation projects [1]. Students in IBL actively engage in real-world engineering projects throughout their undergraduate education. These projects are chosen by the student. This allows the student to direct their own education and shape it into their individual passions and interests. The projects are innovation-based, solving real world problems, with a goal of creating impact outside of the University. This impact can appear in forms such as conference and journal paper publications, patents, and even new businesses to name a few. One example is this peer reviewed journal paper demonstrating the design, build, and testing of a prosthetic leg utilizing additive manufacturing techniques [2].

By allowing students to work on real world projects, they can develop crucial communication and problem-solving skills that exams don't foster [3]. The IBL style of education gives the students an opportunity to learn about how engineering is practiced post-graduation while providing an educational model that doesn't punish failure but encourages pivoting from it. This learning by failure model of learning is crucial in helping students learn from their mistakes and move forward [4] [5]. Learning from failure carries over into the core concepts that they learn in the classroom. Students are not judged only on their first attempt, but rather mastery of core fundamental concepts [6]. This style of acceptable failure education is very useful to measure individual student outcomes in courses [7]. Students are not evaluated on their ability to memorize information before exams, but rather their ability to master certain core concepts and apply them towards growing an innovation project.

This paper explores the implementation of a self-assessment form based on ABET student outcomes and blockchain tokens as a tool to assess ABET student outcomes in these IBL courses. MOOCIBL is a custom-made learning management system (LMS) that facilitates the documentation of student's efforts in the form of blockchain learning tokens [8]. It stores evidence of learning from the mastery of core concepts and evidence of application from the projects. Blockchain based tokens made in our custom-made LMS (MOOCIBL) link to videos, models, designs, and papers that the students create. Some examples of tokens include engineering simulations, presentations on topics, documented engineering failures and the pivots from those failures. After creation the tokens are made available to other students to view. Two students in the same class offer critical reviews of the token compared to their knowledge and mastery of the topic. Peer review in education is a useful tool for students to enhance their learning and develop the ability to take constructive feedback from another student [9]. After review, the student can see the constructive feedback on how the token could be improved to show better knowledge of the topic. With this feedback, the student can make corrections and redo their token before the instructor review to enhance their understanding and knowledge of the topic. The instructors will then review the token for mastery of the core fundamental principle and approve or reject it while giving the student more advice and direction on the concept. The student is not punished for this first attempt, or any subsequent attempt on the mastery of the token. This emulates the system of publishing or reporting scientific findings and

is another step forward in using education to prepare students for the real world. The tokens created in the LMS also showcase entrepreneurship and innovation abilities developed by the students throughout their IBL projects. These tokens show competencies in project management, team collaboration, industry coordination, and overall engineering in the real world. MOOCIBL allows for the tracking of these real-world engineering competencies that display a clear mastery of the ABET learning outcomes taught in the course, such as making measurements from living systems and the ability to function as apart of an engineering team.

Student participation is integral to success in the classroom and success in post-graduation [10]. Students learn better when they have an active participation in their education and curriculum. This is why the students in the University of North Dakota's undergraduate biomedical engineering program include the students in the evaluation of their ABET student outcomes. This study employs the involvement of two senior undergraduate students who have experienced several IBL courses since the Fall of 2022, all of which used the MOOCIBL platform and its blockchain-based tokens. The students were tasked with assigning their previous years tokens to ABET student outcomes at the start of the Fall 2023 semester. The self-assessment form can be found in Appendix A. In general, very few students are aware of ABET or of its student outcomes [11]. By having the students participate in the self-assessment process and reflect on their experiences, each student is able to identify outcomes which have not been achieved and develop a plan to achieve all ABET outcomes prior to graduation. This proactive self-assessment prompts students to identify weak points in their education and has the potential to shape better student outcomes, filling all the ABET student outcomes and preparing students to be well-rounded engineers.[12]. The two senior semesters of IBL allow the students to direct their learning and create their own learning experiences to address these shortcomings. The core fundamental principles during these last two courses are adjusted to better round the student's education outcomes and reflect their personal educational interests and possible career goals.

Methods:

Participants

Two senior undergraduate students were given the self-assessment. The students are enrolled in the biomedical engineering (BME) bachelors' program at the University of North Dakota (UND). Currently, there are 40 students enrolled in the undergraduate BME program with all core courses following the IBL structure of education. The students in this study are the only two current senior students in the undergraduate program. These students both wrote this paper as a part of their continuing participation in their education model. They both have taken multiple BME courses with the IBL structure since the Fall of 2022. All these courses used MOOCIBL's blockchain-based tokens.

MOOCIBL tokens as student outcome evidence

In these IBL courses the students are tasked with keeping track of their core principle and project progress through an online proprietary learning management system called MOOCIBL. These tokens were comprised of links to documents, project research, and presentations showcasing the students' knowledge of the core principle. The platform allows for easy

collaboration and shared documentation of student's efforts. These tokens are archived in the LMS for the students and instructors to reference later. They are also a good metric of core concept mastery and success in the course. As this paper will discuss, these tokens could also be used to measure ABET student outcomes and let students direct their learning.

ABET student outcome self-assessment

The participants in this paper were given a self-assessment in their senior year of IBL. This assessment had them match MOOCIBL tokens to student outcomes defined by ABET. The students filled out their ABET forms and determined what identifiable gaps they had in their student outcomes, or what student outcomes had fewer tokens than desired. From this, they shaped their education moving forward into their senior year to address these gaps, allowing for more fulfillment of student outcomes. The self-assessment form used can be found in Appendix A. It includes 11 main sections referring to ABET student outcomes. For purposes of quantification, 5 main tokens in each area showing mastery of a student outcome are considered a strong token presence. 5 tokens was chosen as an arbitrary metric to ensure that each ABET outcome had sufficient evidence of mastery. Each token is reviewed by instructors to ensure that the content included shows mastery of each topic and that the learning outcome has been achieved.

Discussion:

The results of this study indicate that the combination of self-assessment forms and blockchain-based tokens have positively impacted the assessment of ABET student outcomes. The students were provided the self-assessment after their junior year of IBL. An example of this empty form can be found in Figure 1. They utilized MOOCIBL's token management system to access previously made tokens and assigned them to the ABET student outcomes in the form. The students filled out the form over the course of a couple weeks at the beginning of the semester. Upon completion of the self-assessment forms, they were returned to instructors and discussed. Most areas of student outcomes were filled, but some had only a few tokens that matched the criteria. Overall, about 73% of the sections across both forms had strong token presence with the other 27% having less tokens to represent learning evidence. The self-identification of these weak points empowered the students and instructors to come up with individual plans that satisfies their educational goals.

Item	Proof (Please provide a list of tokens that serve as evidence of your skill acquisition.)
General Engineering	
An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	
An ability to communicate effectively with a range of audiences.	
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	

Figure 1: Empty self-assessment form. This form will be filled in by students at the start of their senior year. They will populate the empty space on the right with tokens from their previous classes.

The self-assessment form allowed these students to actively shape the rest of their education experiences based on self-identified gaps in their ABET student outcomes. They have been updating their self-assessment forms throughout the semester to keep track of their educational progress. Currently, at the start of the second semester in their senior year, the students have filled these gaps with various tokens. They have a strong token presence in most categories, and overall, they are at a combined 96% completion of the self-assessment form. An example of a self-assessment form starting to be fill out vs a form with strong token presence can be found in Figure 2. The successful implementation of the self-assessment form and the LMS's token tracking shows a great potential tool for higher education. By allowing students to participate in their own assessment of student outcomes, it gives the students the autonomy to fill the gaps themselves with customized tokens. This innovative approach allows for better quality control of student outcomes and fosters an open environment with students and instructors cooperating.

Item	Proof (Please provide a list of tokens that serve as evidence of your skill acquisition.)
General Engineering	
An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Token #8620, Token #8502, Token #8507, Token #8644,
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Token #8620, Token #9013,
An ability to communicate effectively with a range of audiences.	Token #6143, Token #5943, Token #8620, Token #8621, Token #8643
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	Token #8444, Token #8643,
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Token #6034, Token #5943, Token #6001, Token #6034, Token #6817

Item	Proof (Please provide a list of tokens that serve as evidence of your skill acquisition.)
General Engineering	
An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Token #8620, Token #8502, Token #8507, Token #8644, ***Token #12347***
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Token #8620, Token #9013, ***Token #12259, Token #12298, Token #12348***
An ability to communicate effectively with a range of audiences.	Token #6143, Token #5943, Token #8620, Token #8621, Token #8643
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	Token #8444, Token #8643, ***Token #12406, Token #12259, Token #13108***
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Token #6034, Token #5943, Token #6001, Token #6034, Token #6817

Figure 2: Start of a self-assessment form filling in the fall (left) vs a fully filled self-assessment form (right) with newly created tokens during the semester. After discussion in the fall, both students and instructors will collaborate to fill the self-assessment outcomes without 'strong' token presence. Through the flexible IBL model, the senior student's education will be shaped to

reflect these outcomes. This self-assessment tool can be useful to determine ABET outcomes when combined with direct assessment by instructors of token evidence.

From the instructor's standpoint, the integration of self-assessment forms and blockchain tokens offers a comprehensive look into the evaluation of student outcomes. Instructors play a crucial role in the validation of token mastery in terms of ABET criteria and core engineering principles. The instructors' review adds a layer of constructive feedback to guide students toward these goals. The adoption of the LMS's's blockchain-based tokens streamlines the review process, allowing instructors to easily access and assess students' knowledge. The utilization of the self-assessment form enhances the quality control of ABET criteria, and the ability to assess these outcomes. The following is an instructors' perspective on the use of MOOCIBL and self-assessment forms as a metric to assess ABET student outcomes.

> *"This self-evaluation empowers students by allowing them to identify their strengths and weaknesses within the standardized ABET student outcome framework."*
>
> *"It's been thrilling to witness students self-assess their progress and assert control over their own learning."*
>
> *"Despite its imperfections, this tool provides an opportunity to systematically incorporate and bring attention to the varied ABET student outcomes within the BME program. Its use allows for a more informed awareness among students about these outcomes, contributing to an understanding of the program's educational objectives."*

The involvement of senior undergraduate students in this study is crucial to understanding the experience from the student's perspective. Their firsthand experiences in multiple IBL courses utilizing the LMS's tokens provide valuable insights into the practical application of IBL learning. As the first students to go through the self-assessment process in this program, their experience is valuable to the development and continued improvement of the IBL structure. The following are student perspectives on the use of a self-assessment form utilizing MOOCIBL's token system.

> *"The IBL platform has given academic freedom to allow me to go further than I ever would've been able to in a traditional model. As an undergrade student I have been able to publish papers, submit research grants, speak at multiple national conferences and more. All because we were given the opportunity to prove what we could do."*
>
> *"Being able to identify weak points in my student outcomes and shape my education to address them is great. I am not only able to shape my education to better fill these outcomes, but I can shape it to better reflect my areas of interest."*

Conclusion:

The integration of self-assessment forms and blockchain tokens in innovation-based learning has promising implications for advancing engineering education. The approach of involving students and professors in student outcomes allows the students to take ownership of their learning outcomes. The proactive involvement of students in assessing their ABET student

outcomes through self-assessment forms has proven to be effective. The identification of weak points and gaps in their education allowed students to tailor their learning experiences to address these areas. MOOCIBL's blockchain tokens played a pivotal role in this process, enabling students to view a comprehensive list of tokens showing documents, project research, and engineering concepts.

The success of this approach is observed in the filling of ABET student outcomes, with the students achieving 96% of their overall student outcome goals after the first semester. The continuous updating of these self-assessment forms with MOOCIBL's tokens reflects the ability of students to actively shape their educational journey. In the future, the UND IBL program is planning implement this self-assessment form for all BME seniors, fostering a collaboration between faculty and students that helps to achieve learning outcomes. This study will hopefully open avenues for further implementation and adaptation of similar approaches in educational settings.

References

[1] R. Striker, M. Pearson, E. M. Swartz, L. Singelmann and E. Alvarez, "21st Century Syllabus: Aggregating Electronic Resources for Innovation-Based Learning," in *2019 IEEE Learning With MOOCS (LWMOOCS)*, Milwaukee, 2019.

[2] N. M. Bittner and G. Christopher, "Additive Manufactured Lower Limb Prosthesis," *Biomedical Sciences Insturmentation,* vol. 59, no. 1, 2023.

[3] E. Alvarez Vasquez, L. Singelmann, E. M. Swartz, M. Pearson and R. Striker, "Student-developed Learning Objectives: A Form of Assessment to Enable Professional Growth," in *ASEE Virtual Annual Conference*, Virtual, 2020.

[4] I. Heizelman, K. House and M. Matt, "Innovation-Based Learning. Learning by Failure," in *ASEE 2023 Annual Conference*, Baltimore, 2023.

[5] A. Arshad-Ayaz, M. A. Naseem and D. Mohamad, "Engineering and humanitarian intervention: learning from failure," *Journal of International Humanitarian Action,* vol. 5, no. 1, pp. 1-14, 2020.

[6] M. Pearson, R. Striker, E. M. Swartz, E. Alvarez Vasquez, L. Singelmann and S. Shie Ng, "Innovation-based Learning: A New Way to Educate Innovation," in *ASEE Virtual Annual Conference*, Virtual, 2021.

[7] E. M. Swartz, R. Striker, L. Singelmann, E. Alvarez Vazquez, M. Pearson and S. Shie Ng, "Innovating Assessment: Using Innovative Impact as a Metric to Evaluate Student Outcomes in an Innovation-Based Learning Course," in *ASEE Virtual Annual Conference*, Virtual, 2021.

[8] E. Alvarez Vazquez, R. Striker, L. Singelmann, M. Pearson, E. M. Swartz, S. Shie Ng and D. Ewert, "The MOOCIBL Platform: A Custom-made Software Solution to Track the Innovation Process with Blockchain Learning Tokens," in *2021 ASEE Virtual Annual Conference*, Virtual, 2021.

[9] K. S. Double, J. A. McGrane and T. N. Hopfenbeck, "The Impact of Peer Assessment on Academic Performance: A Meta-analysis of Control Group Studies," *Educational Psychology Review,* vol. 32, no. 1, pp. 481-509, 2019.

[10] U. Bergmark and S. Westman, "Student participation within teacher education: emphasising democratic values, engagement and learning for a future profession," *Higher Education Research & Development,* vol. 37, no. 7, pp. 1352-1365, 2018.

[11] A.-H. I. Mourad and M. Y. E. Selim, "On the Awareness of Engineering Students with ABET accreditation Elements," *Journal of Education Research,* vol. 4, no. 2, pp. 1-16, 2010.

[12] H. L. Andrade, "A Critical Review of Research on Student Self-Assessment," *Frontiers in Education,* vol. 4, 2019.

Appendix A:
BME 480 – Senior BME worksheet

Up to this point, your proficiency in identifying distinct engineering features of tokens in Moocibl has proven to be a powerful tool for classifying various aspects of all your BME classes within ABET requirements, while also nurturing your professional development. This capability has enabled you to effectively analyze and understand complex engineering concepts and their applications within the biomedical field. As you progress, we now want you to delve deeper into your coursework and provide concrete evidence demonstrating the achievement of each item. By presenting specific tokens and associated evidence, you can showcase your mastery in applying engineering principles to practical challenges, thereby substantiating your growth in both academic and professional domains.

In the pursuit of excellence, it is essential to assess your coursework thoroughly and ascertain the fulfillment of each targeted item. Your meticulous examination should extend beyond the mere identification of engineering features to showcasing how these features have been applied and integrated into your academic projects. By presenting compelling tokens and their supporting evidence, you will present a comprehensive overview of your accomplishments and progress. Moreover, this self-analysis will help you identify any gaps in your current achievements, enabling you to channel your efforts towards those areas during the ongoing semester, ensuring continuous improvement and advancement in your academic journey and professional competence.

Item	Proof (Please provide a list of tokens that serve as evidence of your skill acquisition.)
General Engineering	
An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	
An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	
An ability to communicate effectively with a range of audiences.	
An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	
An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	
An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	
An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	
BME	
Applying principles of engineering, biology, human physiology, chemistry, calculus-based physics, mathematics (through differential equations) and statistics;	
Solving bio/biomedical engineering problems, including those associated with the interaction between living and non-living systems;	
Analyzing, modeling, designing, and realizing bio/biomedical engineering devices, systems, components, or processes; and	
Making measurements on and interpreting data from living systems.	
Professional skills	

Linkedin Profile	
Professional Resume	
Professional behavior	