2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #51025

WIP - A New Standard: Evaluating Innovativeness in Environmental Engineering Solutions

Calvin Leon Wynn, University of Colorado Boulder

Calvin Wynn is a Ph.D student at the University of Colorado Boulder earning a degree in Engineering Education. He has a Masters and Bachelors of Science in Biosystems Engineering with an emphasis on Food Processing.

Dr. Azadeh Bolhari, University of Colorado Boulder

Dr. Bolhari is a professor of environmental engineering in the Department of Civil, Environmental and Architectural Engineering (CEAE) at the University of Colorado Boulder. Her teaching focuses on fate and transport of contaminants and capstone design. Dr. Bolhari is passionate about broadening participation in engineering through community-based participatory action research. Her research interests explore the boundaries of engineering and social science to understand the evolution of resilience capacity, utilizing quantitative and qualitative research methods.

Dr. Angela R Bielefeldt P.E., University of Colorado Boulder

Angela Bielefeldt is a professor at the University of Colorado Boulder in the Department of Civil, Environmental, and Architectural Engineering (CEAE) and Director for the Engineering Plus program. She has served as the Associate Chair for Undergraduate

WIP - A New Standard: Evaluating Innovativeness in Environmental Engineering Solutions

Abstract

Innovativeness in engineering design is often associated with mechanical, electrical, or aerospace engineering, while it remains less emphasized in the field of Environmental Engineering, despite this discipline's critical impact on human health and the environment. This paper presents the development of a Product Innovativeness Rubric for Environmental Engineering (PIREE) to help systematically assess the innovativeness of team-generated products in undergraduate-based courses. Utilizing key innovativeness identifiers, activity categories were developed that reflect the observable innovativeness of products. Evaluators are guided through a simple Likert-based rating process, which provides a holistic innovativeness score. Although designed for Environmental Engineering, the framework is adaptable for other engineering majors through contextual modification of activities and key skills. This paper discusses the rubric's structure, implementation protocol, and its potential to advance research-based assessment of innovation in engineering education.

Background

Innovativeness and creativity are important skills for all engineers. However, some disciplines of engineering are more often associated with innovation than others. Environmental engineers typically create designs that impact human and environmental health and welfare, including municipal drinking water treatment plants, municipal and industrial wastewater treatment or resource recovery facilities, site remediation plans, air pollution control systems, and solid waste recycling. Innovation is likely to look different in these system designs as compared to more product-focused engineering. The work of environmental engineers is often highly regulated. However, innovation is important to incorporate sustainability, balancing social, environmental, and economic factors for current stakeholders and future generations. Environmental engineering work is also frequently interdisciplinary, working with multiple disciplines of engineering, natural sciences (e.g., chemistry, biology, geology, atmospheric science), policy, public health, and social scientists. There is a need to foster the innovation skills of environmental engineering students. This requires that innovativeness can be measured.

In this work, our goal was not to measure innovativeness for the purpose of grading student work. Our goal was to create an analytic, criterion-referenced rubric that could be used to evaluate student artifacts for evidence of innovativeness across multiple dimensions. Although scoring would occur at the artifact level, the goal would be to aggregate the results to assess the extent to which a ram or course supported the development of innovativeness. Often, the artifacts would be created by a team of students, such as a design report. We are interested in the multiple ways in which innovation can manifest within the multiple stages of a project or design, in contrast to previous work which treats innovation and/or creativity as a single criteria within a larger rating and/or does not provide a true rubric with text descriptions of the rating levels [1],[2]. The Engineering Creativity Assessment Tool (ECAT) from Akdemir-Beveridge et al. [3] is a multi-faceted tool, but again is a rating rather than a rubric and rooted in creativity theories rather than innovation.

Methods

Rubric Development

A team of 5 individuals worked together to create the rubric. Two were professors in civil and environmental engineering, with time in industry and experiencing teaching engineering design to both first-year students and environmental engineering senior capstone design. These professors have been collaborating on research to foster innovation confidence and interest among engineering students [4]. The team also included one senior undergraduate student in environmental engineering and two PhD students in engineering education (with backgrounds in Biological Engineering and Graphic Design). The group reviewed published literature related to innovation and creativity in engineering. They also reviewed projects and presentations generated by undergraduate students for a senior-level environmental engineering course (IRB Protocol # 23-0388) to understand different dimensions of innovativeness in this field of engineering. They iteratively proposed categories for the rubric.

The vision was to create an analytic rubric that could ideally be applied in three specific environmental engineering courses. Each course included a team-based, open-ended project that allowed students to be innovative. The courses were: junior-level Water Chemistry; senior-level Contaminant Fate and Transport; and Environmental Engineering Capstone Design.

Rubric Structure

Evaluating innovation in the context of student work is challenging. This complexity stems from innovation being a multi-faceted descriptor. Definitions for 'what can be considered innovative' are continually changing and often contested. Unguided evaluators not using this rubric may evaluate innovation on a binary scale, yes or no. However, most research classifies innovation using multiple concepts to represent innovation, including Ferguson's [5] engineering innovation framework. Another framework for innovation consists of five main concepts: questioning, observing, experimenting, idea networking, and associational thinking [6]. This framework has also been used to develop surveys [7]. After reviewing multiple options, a framework for inventiveness was selected to identify key innovation-related skills. These skills have less to do with content and more to do with how inventive a product is. These inventiveness traits are novelty (Nov), unpredictability (Unpred), creativity (Creat), and uniqueness (Uniq) [8],[9]. These traits are listed and defined in Table 1.

Table 1. Inventiveness traits of a Product (adopted from [8],[9]).

Novelty (Nov)	**Unpredictability (Unpred)**	**Creativity (Creat)**	**Uniqueness (Uniq)**
Does not significantly resemble existing solutions Opposing: Conformity, tradition	Is not easily predicted by an expert Opposing: Certainty, prioritizing stability over variety	Exhibition of artistry, ingenuity, finesse Opposing: Conventional, rigid efficiency, low deviation	Work is unlikely to be recreated by another person from personalization Opposing: Uniform, nondistinct, under-personalized

Table 2 presents the initial set of evaluation criteria and associated rating levels used in the early phase of developing the Product Innovativeness Rubric for Environmental Engineering (PIREE). At this stage, the instrument functioned primarily as a structured rating scale, as detailed textual descriptors had not yet been articulated for each performance level. The criteria in the PIREE are reflected in the Activity Column. We identified ten activities in the design process that might demonstrate innovation or inventiveness traits (shown in column 5). These specific activities were identified within literature and are referenced accordingly – notable for reflecting innovative skills across recorded literature. Assignments being evaluated by the rubric may or may not contain this breadth of activities. We selected a 5-point rating scale ranging from 0 to 4. These values represent five different levels of innovativeness or inventiveness evident in the activity; these are roughly defined in the footnote of the table and further discussed below.

Note that having 10 criteria exceeds the typical number for rubrics used in higher education [10]. It is possible that these could be clustered into 4 dimensions, at least for reporting results, such as: problem framing and constraints (1 and 2), ideation and evaluation (3, 4, 5), technical development and evidence (6, 7, 9), communication and professional practice (8 and 10). Note that some reviewers were concerned that the 10 criteria already contain multiple sub-parts, but larger rubrics become unwieldy, reducing usability and scoring consistency.

Table 2 represents a rating scale rather than a complete rubric. The full text-based descriptors for each activity and each level of the rubric are still being refined. The draft rubric for 3 of the criteria / activities is shown in Table 3.

Table 2: Product Innovativeness ratings for PIREE.

#	Activity [Ref]	Rating 0 to 4*	Criteria Description	Inventiveness Traits
1	Identifying the problem [11]		Identifying stakeholders, what or where the issue is happening, identifying impacts of action/inaction, listing all assumptions	Nov, Unpred, Creat, Uniq
2	Specifying needs and analyzing constraints [12]		Define/prioritize requirements, conversion of needs/wants to function, schedule/spending/resources, regulations	Nov, Unpred, Creat, Uniq
3	Evaluating possible solutions [13]		Dis/Qualifying criteria of alternatives, comparison of alternatives, decision making, evaluation of ethical, environmental, and societal impacts	Unpred
4	Preliminary Visualization [13]		Using visual tools to represent form and function, applying assumptions to appropriate real-world situations, analyzing possible technology for design testing, hypothesizing design behavior	Nov, Creat, Uniq
5	Curriculum-based Reverse Engineering [14]		Justification of design by project requirements, analyzation of components by project requirements and constraints, utilization of class resources for preliminary design evaluation, utilization of class resources for material acquisition	Unpred, Uniq
6	Product Validation [15][16]		Documentation of initial observations, exposing design to real-world situations to document behavior, reporting data from design experiment, outlining core components of tools used in project	Nov, Creat, Uniq
7	Data Analysis [17]		Making conclusions on design behavior based on experimental data, justifying alteration/retention of design components by data, analyzing impacts from altered design/experiment, performing further testing on altered design/analyzing successful design components	Nov, Unpred, Creat, Uniq
8	Technical Communication [18]		Creates an understandable narrative which outlines all aspects of the project, simplifies complex content with figures, diagrams, and other visual/tactile aids, utilizes time effectively to deliver narrative and answer questions, demonstrates professionalism, communication, and accuracy	Uniq
9	Technology Integration [19]		Integrates industry-standard technology for project tasks, utilizes collaborative platforms for team, client, and other professional communication, selects and justifies design resources by cost, performance, and sustainability, performs life cycle analysis	Nov, Unpred, Creat, Uniq
10	Developing Strategic Relationships [20]		Builds/maintains cross-disciplinary relationships, communicates to all parties with punctuality and professionalism, demonstrates equal distribution of work, maintains open communication for ideas/contributions	Creat, Uniq

* Rating levels:
0 – Minimal: no innovativeness or inventiveness demonstrated in this activity
1 – Minor: some small evidence of inventiveness identified, but it is still fundamentally basic in approach
2 – Average: inventiveness is clearly evident
3 – Exceptional: highly inventive or innovative, beyond what is expected.
4 – Renowned: students demonstrate immense innovativeness or inventiveness. Reserved for groundbreaking and exceptional instances of activity utilization.

Table 3. PIREE for three selected activity categories.

Activity / Criteria	Renowned 4	Exceptional 3	Average 2	Minor 1	Minimal 0
Identifying the Problem *Inventively (**Nov, Unpred, Creat, Uniq**) identifies stakeholders, what or where the issue is happening, identifies impacts of action/inaction, listing all assumptions*	Groundbreaking problem identification. Problem is entirely unique & novel, fundamentally creative in approach, and is extremely unlikely others could identify this problem.	Inventiveness traits are all demonstrated exceptionally within the problem identification process. Creativity is obvious. Problem is unique. Reviewer may find the problem difficult to identify on their own.	Proposed problem is innovative. Utilizes multiple (not necessarily all) of the inventiveness traits. Creativity is noticable. Is somewhat unique. Reviewer may find the problem predictable to identify.	Problem identified demonstrates some inventiveness traits. However, is not inventive in overall scope. Does not meet criteria for being innovative.	Problem identified is lacking all inventiveness traits. Generic problem identification, predictable in approach, lacking creativity and may not be unique
Evaluating Possible Solutions *Dis/Qualifying criteria of alternatives, comparison of alternatives, decision making, evaluation of ethical, environmental, and societal impacts; Approach is unpredictable (**Unpred**)*	Evaluation process is entirely unpredictable from what the reviewer knows. Is so ingenious new standards for product development could be formed around this approach. Replication of this process would be impossible.	Evaluation process is formulated from the teams needs, may not resemble traditional evaluation processes. However, is potentially identifiable by others. (Others could possibly replicate this process)	Solution evaluation process is somewhat unpredictable. Teams may use traditional evaluaiton processes, but in unpredictable ways. Process may be replicated across the field, however the team adapted the process to their own needs.	Evaluation process is predictable, but minor adjustments were made that are somewhat unpredictable. Reviewer still finds the predictable nature of the evaluation process in the forefront, despite potential changes.	Evaluation process is predictable. Reviewer has likely seen this process many times before. No effort was made to made this evaluation process any different than what is currently used.
Technology Integration *Integrates inventive (**Nov, Unpred, Creat, Uniq**) technological use into the product design process*	Technology utilized is woven into the design process seamlessly. Both in choice of technology used and in how the technology was integrated. Technology use is creative, unique, not expected by others, and novel to the highest degree. Never-before-seen creation/usage of technology.	Technology is utilized exceptionally well into the design process. Unlikely but creative choices were made in technology usage. Technology may is physically innovative, and utilized in innovative ways. (Using the inventiveness traits) Inventiveness traits are all used to an exceptional degree.	Technology use is innovative, but may not be entirely innovative. Demonstrates the inventiveness traits, but some may be lacking compared to others. Technology choices may not be innovative, but utilization of the technology is. (Or Vice-Versa) May acquire and adapt technology to fit the projects' needs better.	Technology integration is somewhat lacking innovativeness. While usage may demonstrate some inventiveness traits, a majority of the technology used will not demonstrate any inventiveness traits. Generally uses easy to acquire technology, and may do some minor changes.	Technology integration is entirely without innovativeness and inventiveness traits are not demonstrated at all. Project team may utilize technology, but without any demonstratable innovative approach.

Rubric Implementation Protocol

To use the rubric properly, it is important to first identify evaluators. This could be a Professor, Environmental Engineering Expert (Ph.D., Scientist, Currently Practicing Engineer). It is expected that the rubric will function differently based on the skills and background of the chosen evaluator, and therefore, should be acknowledged during use of the rubric. Once evaluators have been identified, they must familiarize themselves with the rubric.

The ratings rationale 'key' should be used to familiarize the evaluator with typical examples of what the activity consists of. These should not be considered an exhaustive list but should instead be used to give the evaluator context and understanding of what is expected from a specific activity.

The course material to be assessed is then reviewed at least once, before applying the rubric to the course material. Upon a second pass, the evaluator will assign a 0 to 4 rating to each activity, ensuring their rating correlates appropriately to the rating levels in the rubric (see examples in Table 3).

Upon assigning a 0 to 4 rating, the rater should explain the rationale for the rating. This should be a bulleted list filled with examples that validate the assigned rating. An example rating is provided below:

- Evaluator gives the '1 – Identifying the problem' activity a rating of '1'.
  Justifications could be (this is an example list and is inexhaustive):
  - Lacking research or proof
  - Problem is already solved

  Further justification can be given as identified by the evaluator.

These ratings can be totaled, and a score can be identified detailing how innovative or non-innovative a specific product is (e.g., design report), based on what was evaluated. It is noted that innovativeness should be used with caution when directly evaluating students, as innovation is highly contextual and should likely be used by instructors as a supplementary tool to evaluate (in addition to traditional methods).

Discussion

The next steps are to develop descriptions for all of the rating levels for all 10 criteria. Then have a group of raters apply the rubric to samples of student work. The levels of interrater agreement should be established, reasons for poor agreement, and then refinements can be made in the language of the rubric. This process might first be completed with the final written reports from the environmental engineering capstone course. The refined PIREE rubric could then be applied in other course contexts (e.g., Fate and Transport, First-Year Projects). Ideally, the rubric would be equally reliable in multiple contexts, but we might also find that changes are needed to better suit the assignment requirements. Establishing rubric validity and reliability is a detailed process [21].

Future work should also consider rater training. For example, we could find 1 to 2 anchor artifacts or excerpts from student work that exemplify the levels which could be used for rater norming. As we apply the proposed rubric to a number of student artifacts, we may find that a 0 to 3 rating scale is more functional (e.g., level 0 no evidence of the skill, 1, limited / procedural / conventional, 2, emerging / partially innovative, 3, clearly innovative).

This rubric can serve dual purposes: (1) as a research instrument to generate knowledge on how students exhibit innovativeness in engineering design, and (2) as a pedagogical tool for instructors when product innovativeness is an explicit learning outcome. While this is designed for Environmental Engineering, the framework is adaptable for other engineering disciplines through contextual modification of activities and key skills. Specifically, by modifying the Rating Rationale 'key', this framework can be adapted for any engineering discipline.

The rubric serves as a research tool in its ability to identify key foundational innovative behaviors – reported as activities. This could then systematically determine innovation strengths among varying demographics, classes, and likewise. Additionally, this rubric can be used as a foundation for future work in pedagogic research concerning student design innovation and project-based learning.

Instructors can also use this rubric to evaluate product innovation, especially when innovation is an explicit learning outcome. Because innovation is varied and difficult to assess as a 'scaled amount', the rubric scores should not be directly converted to a finalized score (or grade). Specifically, rating 4 is reserved entirely for 'groundbreaking and exceptional', which is not feasible for most student teams. Thus, using this rubric as a guideline and making appropriate judgements based on the outcomes, circumstances, and information is recommended.

As a work-in-progress, this rubric is bound by research, but improvements can potentially be made upon real-world application and widespread implementation of the rubric. It should also be noted that while the rubric's original purpose is to evaluate innovativeness for Environmental Engineering students, adaptation of the rubric to meet the needs and goals of other engineering disciplines can be reached, although some work may need to be done to ensure outcomes are met for various other disciplines.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Number 2205067. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation. Special thanks to Julia Hyden, Larissa Schwartz, Anvie Gowrishankar, and Maya Leizerovich for rubric analysis and development, all from the University of Colorado Boulder.

References

[1] N.M. Sharef, H. Hamdan, and H. Madzin. "Innovation-Enhanced Rubrics Assessment for Final Year Projects." *Global Journal of Engineering Education,* vol. 16, no. 3, pp. 107–115, 2014. http://wiete.com.au/journals/GJEE/Publish/vol16no3/05-Sharef-N.pdf.

[2] C.D. Denson, J.K. Buelin, M.D. Lammi, and S. D'Amico. "Developing Instrumentation for Assessing Creativity in Engineering Design." *Journal of Technology Education,* vol. 26, no. 2 2015. https://files.eric.ed.gov/fulltext/EJ1087892.pdf.

[3] Z.G. Akdemir-Beveridge, A. Zaghi, and C. Syharat, "Understanding and evaluating engineering creativity: Development and validation of the Engineering Creativity Assessment Tool (ECAT)." arXiv preprint, 2025. https://arxiv.org/abs/2504.12481.

[4] A. Bolhari and A. Bielefeldt, “Exploring the role of mentorship in enhancing engineering students’ innovation self-efficacy,” *American Society for Engineering Education (ASEE) Annual Conference & Exposition*. 15 pp., 2023. https://peer.asee.org/43649

[5] D. M. Ferguson and M.W. Ohland, “What is Engineering Innovativeness?” *International Journal of Engineering Education*, vol. 28, no. 2, pp. 253–262, 2012.

[6] J.H. Dyer, H. B. Gregersen, and C.M. Christensen, “Entrepreneur behaviors, opportunity recognition, and the origins of innovative ventures,” *Strateg. Entrepreneurship J*, vol. 2, no. 4, pp. 317–38, 2008.

[7] M. Schar, S. Gilmartin, A. Harris, B. Rieken, and S. Sheppard, "Innovation self-efficacy: A very brief measure for engineering students," in *Proc. 2017 ASEE Annual Conf. & Expo*., Columbus, OH, Jun. 2017. Available: https://doi.org/10.18260/1-2--28533.

[8] J.J. Shah, S.M. Smith, and N. Vargas-Hernandez, “Metrics for measuring ideation effectiveness,” *Design Studies*, vol. 24, no. 2, pp. 111–134, 2003.

[9] R. Moore, L. Flynn, S. Couch, N. Detchprohm, W.E. Eagle, J.K. Garner, L.B. Estabrooks, A. Maltese, E.M. Matheny, and A. Talamantes, “Infusing entrepreneurship into engineering design curricula to promote inventiveness: A student-centered approach to inclusive innovation.” In *Proceedings of the 2022 American Society for Engineering Education Annual Conference & Exposition*. (2022, June). (Paper ID #37838).

[10] S.M. Brookhart, “Appropriate criteria: Key to effective rubrics,” *Frontiers in Education*, vol. 3, 2018, doi 10.3389/feduc.2018.00022. https://www.frontiersin.org/journals/education/articles/10.3389/feduc.2018.00022

[11] J.S. Krajcik and N. Shin, “Project-Based Learning,” In *The Cambridge Handbook of the Learning Sciences*, R.K. Sawyer, ed. Cambridge University Press, 2014, pp. 275-297. https://doi.org/10.1017/CBO9781139519526.018

[12] M.K. Milan Maros, M. Fila, M. Levicky and M. Schoberova, “Project-based learning and its effectiveness: evidence from Slovakia,” *Interactive Learning Environments*, vol. 31, no. 7, pp. 4147-4155, 2023, https://doi.org/10.1080/10494820.2021.1954036

[13] P.C. Blumenfeld, E. Soloway, R.W. Marx, J.S. Krajcik, M. Guzdial and A. Palincsar, “Motivating project-based learning: Sustaining the doing, supporting the learning,” *Educational Psychologist, vol. 26, no.* 3-4, pp. 369–398, 1991. https://doi.org/10.1207/s15326985ep2603&4_8

[14] B. Veslemøy, P. Wallin, R.L. Sjursen and T. Bolstad, “New approach and old challenges: challenging engineering students' interdisciplinary understanding through interdisciplinary projects and resources for disciplinary student groups,” *European Journal of Engineering Education*, 21 Jul 2025, https://doi.org/10.1080/03043797.2025.2534649

[15] Ö. Akgün, “Technology in STEM project-based learning,” in *STEM Project-Based Learning: an Integrated Science, Technology, Engineering and Mathematics (STEM) Approach*, R.M. Capraro, M.M. Capraro and J. Morgan (eds.), Rotterdam: SensePublishers, 2013, pp. 65–75. https://doi.org/10.1007/978-94-6209-143-6_8

[16] L. Zhang L and Y. Ma, “A study of the impact of project-based learning on student learning effects: a meta-analysis study,” *Front. Psychol*., vol. 14, art. 1202728, 2023. https://doi.org/10.3389/fpsyg.2023.1202728

[17] M.N. Gul, W. Abbasi, M.Z. Babar, *et al.* “Data driven decisions in education using a comprehensive machine learning framework for student performance prediction,” *Discov Computing* 28, 153 (2025). https://doi.org/10.1007/s10791-025-09585-3

[18] S. Vicente, S. Atwood, K. Degoede, and R. Holcombe, “Exploring engineering students’ learning experiences after participating in a mastery- and project-based learning intervention,” ASEE Annual Conference & Exposition, 9 pp., 2025, https://peer.asee.org/56505
[19] R.A. Bhat, “The impact of technology integration on student learning outcomes: A comparative study," *International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET),* vol. 2.9, pp. 592-596, 2023.
[20] R. Zhang, J. Shi, and J. Zhang, “Research on the quality of collaboration in project-based learning based on group awareness,” *Sustainability*, vol. 15, no. 15, art. 11901, 2023. https://doi.org/10.3390/su151511901
[21] B.M. Moskal and J.A. Leydens “Scoring rubric development: validity and reliability,” *Practical Assessment, Research & Evaluation*, vol. 7(10), 2000. Available online: http://PAREonline.net/getvn.asp?v=7&n=10.