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Supporting Novice Design Educators with the Engineering Design Prototyping Rubric (EDPR) to Standardize Prototype Design Reviews

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Abstract

Prototyping is a central element of the design process, enabling low-stakes, iterative exploration of ideas. However, for many students, the purposes and expectations of prototypes remain ambiguous, limiting their ability to begin prototyping effectively or to evolve prototypes toward functional solutions. This lack of understanding can limit students' ability to gain momentum in starting to prototype or in effectively transitioning between prototype evolutions. While prototyping is an important skill for students to learn, it is equally important for faculty to be skilled enough to provide structured feedback that supports the evolution of student prototyping from rudimentary ideas to functional solutions that achieve design goals. Many tools exist to support students starting to prototype (for example, the 30 min. prototype, the prototyping canvas, low fidelity prototyping), but few tools exist to support novice design educators to score these prototypes and provide student feedback that succinctly describes how to evolve the features and functions of this prototype.

This paper presents the Engineering Design Prototyping Rubric (EDPR), a prototype evaluation rubric developed to align student and instructor expectations during formal design reviews. The rubric builds on an existing tool used over the course of 15 years in a first-year, project-based engineering design course. The original rubric has been used effectively to provide a framework for a structured conversation in formal design reviews; teams showcase their prototypes and describe their process towards achieving design outcomes. The instructors previously found that the original rubric served as a worthwhile tool that allowed student teams to reflect on their progress and was flexible for use with a variety of types of design projects. The tradeoff for this flexibility was that the open-ended nature made it hard to use effectively because it lacked instructions. Furthermore, it was not a valuable tool for novice designers unfamiliar with the structure of design reviews.

The success of the original rubric and its open-ended nature led the authors to consider how this rubric could be redeveloped for use by any instructor in a design course to conduct a formal design review. Thus, we redeveloped the rubric to help students self-assess their work and clearly understand how to improve their prototypes to meet design goals. Our own redesign goals for the rubric were to help instructors communicate expectations clearly and to assess student prototypes in a consistent and predictable way. In this paper, we present the redesigned EDPR as well as some test cases as early evidence of the EDPR's usefulness in other engineering design settings. This paper falls in the DEED thematic area of Teaching, Curriculum, and Pedagogy.

1. Introduction

A prototype is a physical or digital embodiment of critical elements of the intended design, and an iterative tool to enhance communication, enable learning, and inform decision-making at any point in the design process" [1]. The act of prototyping is widely recognized as a core mechanism for iterative learning in engineering design, supporting exploration, communication, realization of tangible ideas, and decision-making throughout the design process. While a large and growing body of literature continues to address prototyping strategies and behaviors (e.g., iterative, fidelity, or component vs. integrated prototyping), comparatively few resources translate this knowledge into practical assessment instruments to help instructors conduct consistent, actionable prototype reviews in authentic classroom contexts that help students reach ever higher levels of functionality. This gap is especially consequential for novice design educators, who may be responsible for evaluating highly diverse prototypes across project domains and fidelity levels while also providing feedback that helps student teams identify the next most productive iteration for their prototype.

Evaluating prototypes is a complex challenge because prototyping is an inherently open-ended activity. Prototyping is also not an activity that engineering students typically have much practice with, so they do not necessarily come into a design class with background knowledge of the expectations for prototyping quality. Thus, a rubric for prototypes must be flexible enough to enable the assessment of a variety of different stages and types of prototypes while also being clear and concrete enough for students or instructors with little experience in prototyping to be able to use it effectively.

Effective rubrics must serve multiple purposes: enabling student self-assessment while providing instructors with evaluation tools that facilitate efficient and consistent evaluation of student work [2], [3]. In a review of effective rubric usage and deployment, Panadero and Jonsson summarized two key factors that affect rubric success when deployed either formatively or summatively: metacognitive capacity of the individuals being evaluated and the assessment interval [2]. Additionally, effective rubrics mediate improved performance by facilitating conversation and increasing transparency in the metrics of success, a factor that can be absent from even well-designed and validated instruments when used by novice instructors [2].

Challenges arise when prototype review rubrics are used by novice design educators, including new faculty members, teaching assistants, and instructors who have limited prior experience conducting formal design reviews. In design courses, instructors must judge a wide range of open-ended information. Related to prototyping, they may have to consider prototype types and fidelity levels across multiple different project domains, not to mention that many of the criteria used by expert reviewers are tacit and difficult to articulate explicitly. As a result, novice reviewers may apply inconsistent standards across teams, focus feedback on superficial indicators of quality, or struggle to identify the most productive "next iteration" for a prototype. Prior work on rubric use emphasizes that while analytic rubrics can improve scoring reliability, this benefit depends strongly on clarity of performance descriptors, the availability of exemplars, and rater training or calibration activities [3]. These concerns are consistent with assessment research showing that inter-rater reliability can be difficult to achieve even with shared rubrics, particularly when evaluators interpret criteria differently or lack shared reference points for what constitutes performance at each level. Thus, prototype review tools intended for broad adoption must balance flexibility with concreteness by making quality indicators visible in the rubric and minimize opportunities for evaluator ambiguity.

For the past 15 years, we have used a prototype review rubric in a first-year engineering design course at Rice University to provide formative feedback and support iteration during prototyping. The rubric was developed to help novice design teams articulate what their prototypes are intended to demonstrate, justify design choices using evidence, and identify actionable next steps across successive reviews. We found that the rubric was effectively aiding in student growth while serving effectively as a grading instrument, but there were also areas for improvement. In this paper, we describe the original rubric and its role in shaping structured prototype review conversations, then present an updated version intended to increase clarity, improve consistency across evaluators, and extend applicability across engineering domains and prototype modalities.

The updated rubric, the Engineering Design Prototyping Rubric (EDPR), is a prototype evaluation rubric intended to support both formative coaching and summative scoring during formal design reviews. In addition to describing the rubric's structure and design rationale, we present the results of deployment in two capstone courses to examine (1) whether the rubric differentiates teams at different stages of progress and (2) whether student self-ratings align with instructor ratings when using the same rubric.

2. Literature Review

While prototyping is one of the most important aspects of the design process, it is also one of the least studied [4]. The common objectives for design prototyping include refinement, communication, exploration, and active learning [5]. Various prototyping strategies have been described, such as iterative prototyping and parallel prototyping [5]. Engineers focus on the features and the functions of prototypes to meet project goals, whereas designers focus on investigating the design space for new possibilities and used a wider variety of prototyping materials and tools, especially for earlier low-fidelity prototypes [6]. The prototyping behavior of engineers and designers becomes more similar in later stages of the design process [6]. Others have written extensive reviews about prototyping, discussing information such as the different types of prototypes and different prototyping strategies [5], [7], [8], [9]. Rather than repeating that information here, the focus of this literature review is to look for strategies and techniques that exist to support student prototyping and to support novice instructors in directing student prototyping activities.

2.1 Novice Designers' Use of Prototyping

Novice designers do not automatically know how to approach prototyping. For example, designers may face concerns with not knowing how many prototypes they should ideally construct and what the nature of the prototypes should be regarding material, level of fidelity and functionality, and testing approach [4]. Deininger and colleagues compared novice designers' reported prototyping versus prototyping best practices. They found that novice designers infrequently used inexpensive early prototypes and infrequently used prototypes to define user requirements, two best practices that would have been helpful if used intentionally. The novice designer participants gave unsophisticated initial descriptions of prototypes, but later after further reflection began to recognize the more specific benefits of using prototypes [10]. Schaefer and Palmgren conducted prototyping workshops with students which included spatial prototyping, multi-material prototyping, physical prototyping, and a mixed approach. They found that the prototyping exercises supported the learning of diverse competencies yet were also counterproductive and met with resistance [11]. Other work has been done to characterize the types of prototypes that student engineers make to better understand how prototypes aid in their learning to be better designers [9]. This work did not yet evaluate whether providing these definitions was helpful to aid student designers. Taken together, the aforementioned findings suggest a need for further research into best practices to support prototyping for novice designers.

2.2 Prototyping Support Tools

Various prototyping support tools have been developed or proposed. Erichsen and colleagues developed a tool to capture prototypes developed in early stages of design projects [12]. These early prototypes are usually low fidelity and discarded, so they believed that documenting them would be important to aid in understanding early-stage design prototyping [12]. Camburn and colleagues presented a methodology for formulating prototyping strategies and enhancing the prototyping process [4]. The method consists of a group of guiding questions and corresponding flowcharts and equations which assist the designer in making decisions regarding how to approach the prototyping process efficiently and effectively [4]. Another tool, "Prototyping Canvas," is intended to aid designers in planning their prototyping by identifying assumptions and questions to guide development [13]. The motivation for developing this tool was because designers often prototype without a clear purpose and these prototypes may not necessarily help drive the design process forward [13]. Finally, the Prototyping for X Framework or PFX includes the lenses of prototyping for desirability, prototyping for viability, and prototyping for feasibility [14]. The Prototyping for X Framework was designed to increase confidence in one's ability to develop prototypes for different conditions.

2.3 Rubrics Used to Support Engineering Design Activities

Rubrics have been widely used in higher education to support both formative and summative assessment, offering transparency in expectations, supporting feedback consistency, and enabling student self-assessment [15]. However, rubrics vary substantially in structure, application, and intention. The term "rubric" can refer to a range of tools, from private scoring sheets to collaboratively filled-out shared documents [16]. Reviews of rubric usage show that analytic, task-specific rubrics can improve rating reliability, particularly when accompanied by rater training and exemplars; nonetheless, rubrics do not automatically ensure valid or consistent judgments in complex, open-ended tasks [3]. This limitation is especially relevant for engineering design prototypes, where quality is context-dependent, and judgments require interpretation of tradeoffs, progress, and appropriateness for the design phase. For this reason, rubrics used in design reviews may function most effectively not as static grading instruments, but as coaching scaffolds that support structured discussion and development of shared understanding between student teams and evaluators.

Rubrics used to support engineering design activities and entire engineering design projects have been discussed in the literature, with new revisions of rubrics appearing to capture aspects such as longitudinal evaluation of projects, or broadening rubrics to encapsulate many activities, or capturing how engineering was employed to drive the project [17], [18], [19], [20]. Although we did not identify any published rubrics designed specifically for the evaluation of prototypes and prototyping activities, others have published rubrics in related engineering design activities. For example, Coso and Pritchett developed a rubric to evaluate and promote students' integration of stakeholder considerations in the engineering design process [17]. The rubric was intended to be used as both a formative and summative assessment tool [17]. Friedmeyer created a rubric which described a 12-step design process. The goal was that students following the steps would practice specific skills within the design process, such as problem solving, communication, and collaboration [18]. Pop-Iliev and Platanitis developed a rubric-based approach for evaluating design competency of engineering students [19]. Finally, Das and Yang developed a rubric designed to assess early-stage design sketches [20]. This rubric informed our work as it provided visual examples along with written descriptions for the rubric criteria.

In 2024, Beigpourian and colleagues sought to combine assessment methods to develop a rubric that could be used longitudinally from cornerstone to capstone [21]. For prototyping they prioritized factors such as the use of representational models to investigate system performance, test design ideas, and demonstrate the iterative nature of feature evolution. This rubric highlights the challenge of evaluating prototypes, in that the degree to which these metrics are rated are dependent upon the skill of the evaluator. Additionally, this rubric can be used across years for multiple design teams but is not inherently designed to be used with repeated application.

Crepau and colleagues developed a rubric for complete design team evaluation that also included aspects related to the prototyping step of the process [22]. Their metrics rated "integration" and "system design" as proxy for the prototyping aspects, which included factors such as "purposeful selection of materials; optimization of manufacturing and system functionality; high system reliability" and "well-integrated system which meets all design constraints." A challenge with this and other rubrics that seek to capture objective ratings for design exploration, is the deficiency of embedding in the rubric a tool that promotes the discussion between the evaluator and the student design team to precipitate growth and iteration. Moving from “has not carefully selected materials” to “has carefully selected materials” is not something that a student team can simply accomplish; further scaffolding and support is needed.

Klein-Gardner and colleagues developed a rubric to score engineering design portfolios [23]. Their rubric included the following metrics related to the prototyping aspect: “construction of a testable prototype,” “prototype testing and data collection plan,” and “testing, data collection and analysis.” There are potential issues with how novice instructors might incorporate these statements and rate them when considering student design work.

We could not identify any publications specifically describing prototyping support tools designed to support grading/assessment of prototypes in design education (and are open to suggestions and comments from reviewers). Thus, we feel that the current work addresses a gap in the literature by providing a rubric to facilitate formative and summative assessment of design prototypes.

Beyond the context of engineering design, there is also work on rubrics in the broader educational literature. Here Dawson performed a literature review and identified 14 design elements important to the creation of rubrics [16]. The 14 rubric design elements are: specificity, secrecy (who the rubric is shared with and when it is shared), exemplars, scoring strategy, evaluative criteria, quality levels, quality definitions, judgement complexity (evaluative expertise required of users of the rubric), users and uses, creators, quality processes (to ensure reliability and validity of the rubric), accompanying feedback information, presentation, and explanation (instructions or other additional information provided to users). Given our purposes of creating a rubric that can be used by novice design educators and students, the design elements that are most relevant include: specificity, exemplars (should be included), evaluative criteria, quality levels, quality definitions, judgement complexity (should require low expertise), presentation (should be clear), and explanation (should be accompanied by clear instructions for use).

3. Methods

3.1 Development of Original Rubric

The original rubric was developed in a first-year engineering design course at Rice University, a course which serves as the foundation of the engineering design lab’s curriculum. In the first week of the semester, students are introduced to authentic, real-world projects proposed by external clients drawn from the healthcare community, the local zoo, and other local and global partners. Student teams work over one semester to progress through core phases of the design process, including background research, definition of design criteria, ideation and down-selection, prototyping, and early-stage testing. A substantial portion of the course (~50%)

emphasizes hands-on fabrication and prototyping using resources available in the engineering design lab as well as what the students can order from sources online. (For more information about the formation of this course please see [24]).

The rubric was originally created to structure formal design review conversations that foreground functional progress, defensible decisions, and iteration. Rather than functioning solely as a grading tool, the rubric was designed as a coaching scaffold to help teams communicate what their prototype currently demonstrates and what improvements were still needed. To make evaluation concrete while accommodating diverse project directions, teams were prompted to identify three core features or functions of their proposed solution and to discuss how each feature mapped to their self-stated goals and the design criteria they established through stakeholder conversations. Across the semester, rubric performance levels were intended to represent prototype maturation and increasing alignment with requirements, ranging from early-stage progress ("just starting") through partial functionality ("approaching functionality," "works somewhat") to full target performance ("meets all goals") for each feature or function. Over time, this structure enabled repeated use of a consistent framework while allowing teams to tailor discussion to the most salient elements of their design.

3.2 Implementation of Original Rubric

The rubric was implemented during three formal design reviews distributed across the semester. During each review, teams presented their current prototype state and supporting rationale, and instructors used the rubric to guide a structured discussion of prototype intent, progress, and evidence of performance. These review conversations emphasized not only what the team had built, but also *why* design decisions were made, what testing had been performed or was planned, and what next steps were required to improve function or better meet design criteria [24], [25].

Over repeated course offerings, the rubric served several consistent instructional functions. First, it helped establish a shared language between students and evaluators for describing prototype maturity, reducing reliance on implicit or reviewer-specific expectations. Second, the rubric supported formative feedback by making the "next most important iteration step" more explicit, encouraging teams to connect prototype testing evidence and mentor-informed criteria to result in tangible design changes. Third, the rubric served as a coordination tool during reviews involving multiple stakeholders (e.g., teaching assistants, instructors, and in some cases project partners), helping align feedback around agreed-upon features and performance expectations. We often shared this feedback and next steps with the stakeholders to ensure that there was alignment throughout and that advice would be shared with the team to help them progress [24], [25].

At the same time, sustained use of the rubric revealed recurring implementation challenges that motivated the updates presented in this work. In particular, the rubric's open-ended structure, intentionally flexible, introduced ambiguity in interpretation across different evaluators and projects, especially for novice instructors or teaching assistants, and especially when onboarding new professors into the class, which occurred regularly. Additionally, student teams sometimes approached the rubric as a checklist rather than an instrument for evidence-based reflection, limiting its effectiveness as a learning scaffold unless explicitly framed as formative. These insights informed the redesign goals described later in the paper: improving clarity of performance descriptors, supporting more consistent interpretation across evaluators, and strengthening the rubric's usability as a shared tool for both assessment and coaching.

3.3 Process of Updating Rubric

The rubric revision process focused on reducing instructor ambiguity while preserving the flexibility needed to assess diverse prototypes across multiple engineering disciplines. Besides minor rewording for clarity, two major updates were introduced. First, visual exemplars were added to the prototype evaluation section to provide concrete anchors for scoring levels and reduce reliance on tacit interpretation. This decision was informed by prior work by Das and Yang demonstrating that rubric criteria paired with visual examples can improve clarity and usability, particularly for novice evaluators [20]. Second, a dedicated dimension was added for electronics, which expanded the rubric's applicability to projects in electrical and computer engineering contexts. The electronics performance descriptors were developed through consultation with an experienced capstone instructor in that domain, who provided both content recommendations and proposed level differentiators. Collectively, these updates were designed to support consistent scoring, improve student understanding of expectations, and make the rubric usable as a shared coaching tool during prototype reviews.

3.4 Updated Rubric: The Engineering Design Prototyping Rubric (EDPR)

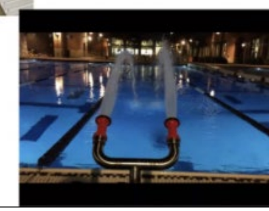
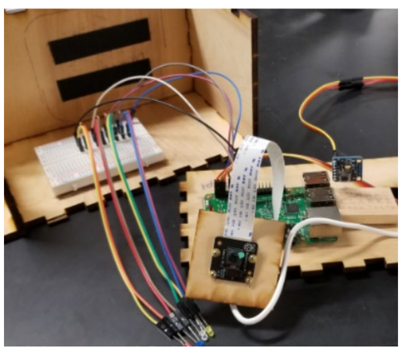
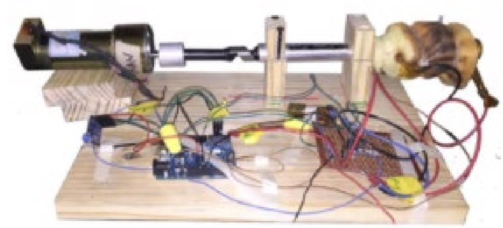
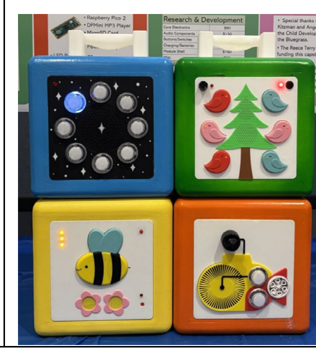
The updated rubric is an analytic instrument with two sections: (1) a design process progress section (marks for iteration, testing, and consistent progress; see Table 1), and (2) a prototype evaluation (marks for quality, intention, materials, and electronics if applicable; see Table 2). Each dimension is scored on a three-level scale, with higher scores indicating greater maturity, fidelity, and alignment with design goals. The design-progress dimensions emphasize evidence of iteration and learning through testing, while the prototype dimensions emphasize whether the artifact appropriately demonstrates intended functions using materials and implementation choices suitable for the project's current phase. The rubric is intended to be co-used by student teams and evaluators during design reviews to structure conversation, elicit rationale, and identify actionable next steps. The full EDPR is presented in Tables 1 and 2.

Table 1. Section One of the EDPR: Design Process Progress

	1 - low	2 - medium	3 - high
Iteration	- Design fixation limited evolution of the prototype - Team "kept making the same thing"	- One or two revisions with limited evolution of design	- Prototype evolved over multiple revisions - Pieces/parts refined and integration/cohesion improved over time
Testing/evaluation of objectives and of prototype	- No testing/poor testing/ineffective testing	- Testing/evaluation of the prototype was completed - Some improvements made based on testing	- Testing/evaluation drove design changes - The prototype may have been damaged or destroyed to make changes
Consistent progress	- Fear of failure affected progress, or fear of starting stunted launch - Slow or limited progress of prototyping	- Uneven or slow progress (started late and caught up or started strong and petered out) but made adequate progress towards design objectives	- Consistent progress throughout the semester - No fear of failure/starting - Teams did not have design fixation or escaped from it

Table 2. Section Two of the EDPR: Prototype Evaluation

	1 - low	**2 - medium**	**3 - high**
Quality of Assembly	- Materials are joined with low-fidelity adhesives and fasteners (e.g. duct tape, clamps). - Sharp edges, structural issues, parts poorly sized and shaped. 	- Combination of low-fidelity and secure joining. 	- Materials are well sized and shaped and are joined together securely. - No unintended sharp edges. 
Intention in Design	- Components are mismatched and fit together poorly. - The project has many loose ends that are not accounted for. 	- Some components fit well together but some do not. - Minimal missing features, most features accounted for. 	- Components are carefully designed to match and fit together. - All parts of the prototype serve a specific purpose, and no key components are missing. 

	1 - low	2 - medium	3 - high
Material Selection	- Materials are low-fidelity or inappropriate for the project. - Materials are off-the-shelf products with no customization. 	- Materials are a mix of low- and high-fidelity. - Materials are a mix of off-the-shelf and customized. 	- Materials are medium-/high-fidelity and well selected for the project. - Components are designed or specially ordered. 
Electronics (if applicable)	- Electronics are prototyped with a breadboard and not secured. 	- Electronics are prototyped with a perf board and are partially secured. 	- Electronics are prototyped with a custom PCB, fully secured, and enclosed in housing. 

3.5 Implementation of the EDPR

We tested the updated EDPR in two courses at the University of Kentucky. Author one was involved in collaborations with these two courses at the University of Kentucky and thus had the ability to utilize the rubric with students and instructors. Our approach to testing the rubrics was guided by dual goals of getting valuable information while also not causing too much of a burden on the lead instructors of the courses. Since we brought in the rubric relatively late in the semester, the rubric was not part of the students' grades, and students and instructors filled out the rubric for the purpose of trialing the rubric. Because our goal was to investigate the usefulness of the rubric for others, we intentionally provided minimal instruction to the students and instructors who filled out the rubric. We asked them to assign a score for each rubric category by circling the desired box, and we reminded the students that projects that were still in progress would be unlikely to receive "3s" in the second section of the rubric. We also reinforced the fact that the rubric scoring would not affect their grade and encouraged them to be honest in their self assessments. The approach to testing the rubric in each course was slightly different and was based on the lead instructors' availability to participate in the testing.

In the electrical and computer engineering course, the instructor team was more heavily burdened with grading at the time we were testing the rubric, thus, we tested the rubric only with students. The electrical and computer engineering capstone course is relatively large and runs two cohorts of students simultaneously. One cohort starts the capstone project in the spring semester and completes it in the fall, and the other starts the capstone project in the fall and completes it in the spring. Thus, by testing the rubric with all students in the capstone course, we tested it with students who were halfway done with their capstone projects and fully done with their capstone projects. This gave us an opportunity to compare the progress of two groups who theoretically should have a clear difference in the state of their prototype's development, with the second semester students having a "completed" prototype, and the first semester students having an "initial" prototype. We had the student teams assess their prototyping on the rubric during the capstone demo day. The student teams filled it out together and came to a consensus regarding scoring. The students were told that it was not for a grade and encouraged to give an honest assessment of their work. There were 14 teams in their first semester of the course, and four teams in their second semester. Each team had four to six students on it.

The following research questions pertain to this part of the study:

RQ1A: Is there a difference between the rubric scores in the design process section for the students in first semester and second semester of the capstone course?

We expect that there is not a difference, as all groups should have been progressing their prototypes during both semesters of the capstone course, so their scores should be similar in the design progress section.

RQ1B: Is there a difference between the rubric scores in the prototyping section for the students in first semester and second semester of the capstone course?

We expect that there is a difference, since the second semester students should have a further developed prototype than the first semester students, so their scores should be higher in the prototyping section of the rubric.

The second course in which we tested the rubrics was a biomedical engineering capstone course. This course had seven teams of five to six students. In this course, student teams developed novel medical devices with the support of a clinical collaborator. The medical devices did not necessarily include an electronic component. (More information about the course is available in this article [26]). The students participated in a rubric scoring activity on the last day of their first semester of the capstone course, at which point their projects were about halfway done, since the course lasts two semesters. The students were told that the rubric was being tested and that the way they rated themselves would not impact their grade. Thus, they were encouraged to give an honest assessment of their work. The student teams agreed on ratings by coming to a consensus as a group. The lead instructor later used the rubric to score each student team without knowing how the student teams had rated themselves. We then compared the student and instructor ratings.

The following research question pertains to this part of the study:

RQ2: Is there a difference in how the students rated their own work versus how the instructor rated the work?

We expect that there is not a difference, as the rubric should be equally understandable by students and instructors.

4. Results

4.1 Electrical and Computer Engineering Capstone Course Results

Semester 1 students were in their first semester of the capstone course in Fall 2025. Semester 2 students were in the second semester of the capstone course in Fall 2025, having started the course in Spring 2025. There were fewer students in this cohort, since most students complete the capstone course in a fall-spring sequence. Two teams failed to complete the second page of the rubric which contained the prototype questions, so they are included only in the analysis of the design questions. The mean scores of each group are presented in Table 3.

Table 3. Mean scores of electrical and computer engineering capstone students

Rubric Category	**Semester 1**		**Semester 2**	
	Mean	**SD**	**Mean**	**SD**
Design: Iteration	2.29 (N = 14)	.611	2.25 (N = 4)	.500
Design: Testing	2.29 (N = 14)	.611	2.50 (N = 4)	.577
Design: Progress	2.50 (N = 14)	.519	2.50 (N = 4)	.577
Prototype: Quality	1.46 (N = 13)	.660	2.33 (N = 3)	.577
Prototype: Intention	2.31 (N = 13)	.480	2.67 (N = 3)	.577
Prototype: Material	2.15 (N = 13)	.555	2.67 (N = 3)	.577
Prototype: Electronics	1.58 (N = 13)	.669	2.67 (N = 3)	.577

Since rubric scores are ordinal, not continuous, we determined that the Mann-Whitney U Test was appropriate to compare the rubric scores for students from semesters one and two. The data passed three assumptions of the Mann-Whitney U Test, which are: the dependent variable is ordinal, the independent variable is two different independent groups, and no participant is in both groups (independence of observations). In some cases, the data from each group did not have the same shape when we compared the histograms, thus, we proceeded to use the Mann-Whitney U Test to compare mean ranks rather than median scores. The results of the Mann-Whitney U Test are presented in Table 4.

Table 4. Results of Mann-Whitney U Test used to compare scores of students in their first and second semesters

Rubric Category	**Semester 1 (N=14) Mean Rank**	**Semester 2 (N=4) Mean Rank**	**Mann-Whitney U**	**Exact Significance *p***
Design: Iteration	9.61	9.13	26.5	.853
Design: Testing	9.14	10.75	23.0	.546
Design: Progress	9.50	9.50	28.0	1.000
Prototype: Quality	7.50	12.83	6.5	.054
Prototype: Intention	7.96	10.83	12.5	.262
Prototype: Material	7.81	11.50	10.5	.156
Prototype: Electronics	6.88	12.50	4.5	.036

Research Question 1A asked if there is a difference between the design process scores of the students in the first semester and second semester of the capstone course? (H0: There is no difference. H1: There is a difference.) No significant differences were found in the design scores, and there was no consistent pattern in which cohort had higher mean ranks.

Research Question 1B asked if there is a difference between the prototyping scores of the students in the first semester and second semester of the capstone course. (H0: There is no difference. H1: There is a difference.) A significant difference was found only in the "electronics" category (U = 4.5, p = .036). However, the mean ranks of the second semester students were all higher than the first semester students, as were the mean scores (see Table 1).

4.2 Biomedical Engineering Capstone Course Results

In the biomedical engineering capstone course, student teams and the lead course instructor provided independent ratings of each project. There were seven student teams and one instructor. The mean ratings are provided in Table 5.

Table 5. Mean ratings provided by biomedical engineering instructor and students

Rubric Category		**Ratings**	
		Student Rating	*Instructor Rating*
Design: Iteration	Mean	2.14	2.57
	SD	0.69	0.54
Design: Testing	Mean	1.86	1.86
	SD	0.38	0.38
Design: Progress	Mean	2.14	2.00
	SD	0.38	0.58
Prototype: Quality	Mean	2.00	2.14
	SD	0.00	0.69
Prototype: Intention	Mean	2.14	1.43
	SD	.38	0.54
Prototype: Material	Mean	1.14	2.00
	SD	.378	0.00
Prototype: Electronics	Mean	1.00	1.00
	SD	0.00	0.00

Since rubric scoring data is ordinal, not continuous, we opted to use the Wilcoxon Signed Rank Test to compare paired samples of observations, which were the student ratings of their own team's work versus instructor ratings of that team's work. The results of the Wilcoxon Signed Rank Test are presented in Table 6.

Table 6. Results of Wilcoxon Signed Rank Tests

Rubric Category		**Results**
Design: Iteration	Z	-1.732[a]
	Sig. (2 tailed)	.083
Design: Testing	Z	.000[b]
	Sig. (2 tailed)	1.000
Design: Progress	Z	-.577[c]
	Sig. (2 tailed)	.564
Prototype: Quality	Z	-.577[a]

	Sig. (2 tailed)	.564
Prototype: Intention	Z	-2.236[c]
	Sig. (2 tailed)	.025
Prototype: Material	Z	-2.449[a]
	Sig. (2 tailed)	.014
Prototype: Electronics	Z	.000[b]
	Sig. (2 tailed)	1.000

a. Based on negative ranks, b. The sum of negative ranks equals the sum or positive ranks,
c. Based on positive ranks.

The Wilcoxon Signed Rank Test showed that biomedical engineering students and their instructor did not provide statically significant differences in ratings on any rubric categories except “Prototype: Intention” ($Z = -2.236$, $p = .025$) and “Prototype: Material” ($Z = -2.449$, $p = .014$).

5. Discussion

This study provides early evidence that a redesigned prototype evaluation rubric, the EDPR, can function as a shared scaffolding tool for design reviews across two distinct engineering capstone disciplines. In the electrical and computer engineering course, the mean ranks of the electrical engineering students scores for the second semester were all higher than the mean ranks for the first semester, although statistical significance was only shown in one of the dimensions (electronics). This result aligns with expectations for a multi-semester capstone sequence in which functional electronics implementation typically advances substantially between the first and second semester. These findings suggest that the prototype-focused dimensions may be sensitive to meaningful progression but that larger sample sizes are needed to confirm reliability and strengthen inference. Further iterations of this analysis are needed with a greater number of teams to confirm the findings, since only four teams in our study were second semester teams.

In the biomedical engineering capstone course, students and the instructor provided statistically different ratings for the prototype intention and materials categories. These differences are pedagogically informative: students rated intention higher than the instructor, which may reflect a tendency to interpret “intention” as clarity of internal team goals rather than the degree to which prototype behavior demonstrates claims to an external reviewer. Conversely, the instructor rated the materials higher than the students, potentially reflecting expert recognition that the materials were appropriate for the current stage of development, even if not representative of final manufacturability. This pattern is consistent with prior rubric research indicating that evaluators can apply criteria differently unless descriptors are paired with shared anchors, exemplars, or calibration [3]. Practically, these mismatches represent an opportunity for instructor and student. The rubric can surface precisely where student and instructor expectations diverge, thereby supporting more productive design review *conversations* focused on “what counts as evidence” and “what is appropriate at this stage.” No significant differences were found between the student and instructor ratings in the other five categories of the EDPR, suggesting that overall, the rubric enabled a fairly consistent evaluation of student prototyping work by students and instructors.

More broadly, this work contributes a pragmatic instrument that translates prototyping research into a classroom-ready assessment scaffold. While rubric-based scoring is insufficient on its own to ensure valid judgments, analytic rubrics can support more reliable evaluation when they include clear descriptors, minimize ambiguity, and are paired with shared reference points. The inclusion of visual anchors and a domain-relevant electronics dimension in the EDPR represent a concrete step toward making prototype assessment more accessible to novice design educators responsible for evaluating diverse artifacts and providing actionable feedback.

5.1 Limitations

In the present study, we tested the EDPR with only a few engineering disciplines: electrical and computer engineering (a combined capstone course with two majors) and biomedical engineering. The original rubric was used in a general first year engineering design course. Thus, the main limitation of the present work is that the EDPR has only been tested with a limited number of engineering disciplines. Future work should test the usefulness of the rubric in other disciplines with a prototyping emphasis in their capstone courses, such as mechanical engineering. Future work should also test the rubric with a larger number of second semester design teams.

6. Conclusion

Prototyping is central to engineering design learning, yet instructors, and in the case of this paper, novice design educators, often lack practical tools for evaluating diverse prototypes consistently during design reviews. In this paper, we present the EDPR, a redesigned prototype evaluation rubric evolved from a well-used prototype evaluation rubric and updated it to reduce ambiguity through visual cues and expanded its applicability through the inclusion of an electronics dimension. Early deployment in two capstone contexts suggests that the rubric can differentiate teams at different stages of prototype development and can reveal systematic differences between student self-assessment and instructor evaluation in specific prototype dimensions. Future work will expand usage to measure reliability across multiple raters, institutions, and disciplines. Additionally, we plan to refine performance descriptors using observed disagreement patterns between students and instructors and evaluate whether rubric-guided reviews measurably improve prototype iteration quality over time.

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