GIFTS: Assessing Teamwork and Design Habits in a First-Year Engineering Design Course

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Introduction

In this Great Ideas for Teaching Students (GIFTS) Paper we present the motivation, background, evolution of development, and practical implementation details of a “team performance and design habits rubric” in a first-year engineering design course (ENES100) at University of Maryland (UMD).

Background

Every engineering student at UMD takes ENES100 during their time as an undergraduate engineering student, and students are tasked with working in a multidisciplinary team of eight (8) students to design and build an autonomous vehicle that can complete a prescribed mission. The learning objectives of the course include 1) applying modeling techniques in engineering design, 2) creating prototypes of the design, 3) troubleshooting and iteration of the design, 4) teamwork and communication, and 5) project management. Thus, in addition to developing the essential skills for engineering design practice, key objectives of ENES100 include building the skills to work equitably on a team, communicate effectively with teammates, and manage a complex engineering project.

Motivation

Out of the learning outcomes listed above grew a need for a tangible way of assessing the team’s operational performance and design habits. While assessing the performance of the autonomous vehicle is fairly straightforward, assessing the team habits and design practices of a team is more difficult. Additionally, a framework was needed for students to reflect on their team’s operational behavior and their team’s design habits so that they could better understand what was needed for success in this course and beyond. To address these needs, the team of instructors for ENES100 developed and implemented a “Team Performance Rubric”.

Although there are many tools and software that are available for assessing the performance of a team and gathering peer evaluations [1], a novel aspect of the rubric is a reflective and responsive approach for assessing design practices within the team. A rubric was developed for rating a team’s engineering design process habits, such as"effective use of modeling techniques” and “design iteration,” as well as the team’s effectiveness, such as “productive discourse” and “failure, resilience, and learning from setbacks.” The rubric for design habits and team practices drew inspiration from existing literature [2] and available tools [1].

The Team Performance Rubric provides multiple performance criteria, a rating scale, and performance indicators relevant to team and design habits. The number of criteria, number of options in the rating scale, and the wording of the performance indicators have evolved over time to provide more clarity. This evolution is discussed below.

Objectives

This GIFTS paper introduces the Team Performance Rubric developed by the authors and offers an overview of its strengths and limitations, as assessed by the instructional team of ENES100. The authors share the lessons learned from developing this rubric, as well as share the rubric itself with the greater engineering education community, in the hopes that others may benefit from using similar rubrics when teaching team-based design courses.

Assessment Methods

The team performance and design habits rubric was developed by the ENES100 community of practice (CoP) [3] which meets regularly to discuss instructional challenges and to learn from the collective experiences and knowledge of the entire instructional team with the shared goal of continually improving both instructional practices and student outcomes. The method employed in this study is action research [4, 5] in which practitioners develop an intervention, implement the intervention, analyze the results, and draw conclusions. In the remainder of this paper we discuss the action research process we undertook to identify an instructional challenge (assessing team performance), the solution our CoP developed (the design habits rubric), our experiences implementing this assessment tool, and our analysis of the strengths and weaknesses of this tool. We present two of the multiple versions of this assessment instrument to highlight the iterative and methodological process undertaken.

Practical Implementation Details and Discussion

History of Rubric Implementation

The ENES100 instructional teaching team created a working group during the spring of 2019 with three goals: a) more closely align the course activities and assessments with the course learning outcomes, b) reward student teams for their engineering design process instead of just the product, and c) more consistently grade students' engineering design work across a large number of sections and instructors.

A small working group came together and drafted the first version of a Team Performance Rubric (Appendix A). Within the five course learning outcomes, the working group identified ten "team design habits" that student teams would need to hone during the semester-long design project in order to meet the course's learning outcomes. These team design habits included: equitable teamwork; productive discourse; communication tools and techniques; integration planning and implementation; making; craftsmanship; calibration and testing; failure, resilience, and learning from setbacks; analysis; and design iteration. These habits were put into the rubric with three rating levels: exemplary, satisfactory, and poor. Performance indicators were provided for each team design habit's rating levels.

The working group shared the first version of the Team Performance Rubric with the larger ENES100 instructional team for feedback. Overall, the instructional team was supportive of this

first attempt at communicating to students the value of the team's process. The primary question that arose was: how will these team design habits be assessed and how will team performance be factored into grades? The instructional team discussed and decided that half of the performance milestone grades would come from traditional product performance and half would be based on team performance.

There are traditionally three performance milestones in ENES100: Milestone 5 (MS5) - Systems Performance, Milestone 6 (MS6) - Systems Integration Performance, and Milestone 7 (MS7) - Final Performance. The instructional team decided that to earn full credit on team performance for MS5, a team would need to provide sufficient evidence to rate eight team design habits at or above the satisfactory level by the due date. That evidence could be observed and signed off by the instructor, or students could write up and submit a reflection on team performance citing evidence and providing justification for the rating the team has earned. To earn full credit on team performance for MS6, a team would need to provide sufficient evidence to rate three habits at the exemplary level and five at or above the satisfactory level by the due date. To earn full credit on team performance for MS7, a team would need to maintain or exceed the rating expectations for MS6.

The instructors provided critical feedback during and in between semesters that influenced the ongoing evolution of the Team Performance Rubric. Instructors observed that certain habits were highlighted or de-emphasized at different points in the project. They noted that it was difficult to differentiate between exemplary and satisfactory ratings. Instructors recognized that student teams were incentivized to give themselves glowing reviews of their team design habits rather than to have honest reflections and strive for growth. Some instructors felt a sense of subjectivity around observing and signing off on teams' habits during their limited class time interactions. This feedback contributed to updates to the rubric itself, how the rubric is used, and how team performance impacts grades.

What follows are the main aspects of the Team Performance Rubric that evolved, leading to multiple rubric iterations that culminated with the current rubric (Appendix B). The rating scale was reduced from 3 options to 2. The 10 design habits - 2 for each of the 5 course learning outcomes - were reduced to 9 total habits. The wording of the performance indicators were modified for clarity. The option for an instructor to observe team performance was removed and replaced with team write-ups. In line with the "reflect on process" design strategy of Crismond and Adams [2], a facilitated activity (Appendix C) was developed to have teams actively reflect on and discuss their team's performance and design habits using this rubric. Teams were challenged to identify indicators that reflect their team, strategies that are currently helping the team or could use improvement, and suggestions for improving a particular habit moving forward. Instead of asking teams to justify that they performed a certain number of habits at the "exemplary" level by a certain time, teams were asked to provide a quality reflection and evidence of growth, and their grade was based on the quality of this reflection. The portion of the performance milestones' grades that came from team performance was reduced from 50% to 25% and then became optional. Reasons for why some instructors have decided to continue or discontinue the use of this rubric are addressed in the Strengths and Limitations section below.

Strengths and Limitations of Rubric

A clear strength of the rubric is that it reflects the learning outcomes of the course that are not captured directly in other course assessment rubrics. Given that students often become hyper-focused on the minutiae of their project's electronics, coding, or manufacturing, having this rubric tied to their grade sends a message to students that we value teamwork, communication, and project management learning outcomes as highly as their ability to build a working robot. An additional strength of the rubric is that it provides the scaffolding for assessing the team-based learning outcomes of the course in a way that is separate from the product's performance. The rubric provides explicit performance indicators that give the students a clearer idea of what we, as instructors, hope their team exemplifies. The rubric removes the ambiguity that comes from asking a question like "How would you rate your team's performance?" Additionally, some instructors use this rubric as part of a 20-minute facilitated activity (Appendix C) that guides teams through how to effectively use this rubric.

One limitation of using this rubric is the challenges that arise when grading something subjective. As pointed out in the History of Rubric Implementation section above, some instructors have teams use this rubric to reflect, and then assign team grades based on the quality of reflection and evidence of growth. Some instructors have struggled with teams providing shallow evidence or reflections that felt forced, leading to difficulty in assigning a team grade for this assignment. An additional limitation of the rubric is that there is some overlap between the performance of individual team members and the rubric items on the team performance rubric. For example, if there is a student who consistently fails to provide quality work and does not pull their weight, this will be assessed both in the individual peer evaluations and the team performance evaluation for "Equitable Teamwork."

Suggestions for improvement

To address the last limitation mentioned above, one suggestion for improvement is to incorporate a reflection that challenges teams to identify how the performance of individual team members affects team performance. Additionally, returning to some level of consistency of use among sections of the course would ensure that all sections, regardless of instructor, have a method of assessing the learning outcomes of teamwork, communication and project management.

References

[1] M.L. Loughry, M.W. Ohland, D.D. Moore, "Development of a Theory-Based Assessment of Team Member Effectiveness," *Educational and Psychological Measurement*, vol. 67, no. 3, pp. 505-524, June 2007.
[2] D. P. Crismond and R.S. Adams, "The informed design teaching & learning matrix," *Journal of Engineering Education-Washington*, vol. 101, no.4, pp. 738-797, Oct. 2012.
[3] J. Lave and E. Wenger, *Situated learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press, 1991.
[4] E. T. Stringer and Alfredo Ortiz Aragón, *Action Research*. SAGE Publications, 2020.
[5] J. Mcniff, *Action research : principles and practice*. Milton Park, Abingdon, Oxon ; New York: Routledge, 2013.

Appendices

Appendix A: Spring 2019 Rubric Version (First iteration of rubric)

Team Performance Rubric for Milestones 5, 6, and 7

		Design Habits: Some Sample Evidence and Ratings		
		Exemplary	**Satisfactory**	**Poor**
Teamwork and Communication	**Equitable Teamwork**	Take on new tasks readily. Deliver early and seek feedback. Team articulates the big picture.	Contribute when asked. Deliver on time. Focus on tasks completion.	Work late or incomplete. Others 'pick up slack.' No equitable team work.
	Productive Discourse	Feedback and discussion routine. Conflict is productive. Excellent cross-team performance.	Feedback and discussion is ad hoc. Conflict is managed. Sub-teams are productive.	Feedback and discussion absent. Team avoids conflict. Members are isolated.
Project Management	**Communication Tools and Techniques**	Comfortable with multiple roles. Team is self-directed and shares goals. All goals are SMART (linked online).	Comfort with individual roles. Individuals have goals. Some goals are SMART.	No roles followed on the team. Goals not communicated. Vague and diffuse communication.
	Integration Planning and Implementation	Co-development occurs fluently. System integration is a planned step. Complexity builds smoothly as planned.	Co-development occurs. System integration works. Complexity builds suddenly under deadline.	Co-development absent. System integration conflicts. System complexity ignored or plan flawed.
Prototyping and Testing	**Making**	Many prototypes showcase ideas. Substantial evidence of skill development. Safety is paramount.	Some ideas are prototyped. Individuals have nacent experience. Safety is practiced.	Prototypes are largely absent. Individuals show no engagement. Safety is ignored.
	Craftsmanship	Final products are polished. Build exceeds design specifications. OSV functions.	Product demonstrates care. Build meets design specfications. OSV may not funtion.	Product is thrown together. Not built to design specifications. OSV appears 'built to work.'
Testing and Troubleshooting	**Calibration and Testing**	Calibration is customized. Test data are comprehensive. Testing plans followed.	Routine calibration verified. Test data exist for sub-teams. Testing as needed.	Calibration not understood. Test data is insufficient. Tests flawed.
	Failure, Resillience, and Learning From Setbacks	Failures are a design priority. Persistence is encouraged. Mistakes are learning moments.	Failures lead to slow growth. Persistence is demonstrated. Mistakes are minimized.	Failure is unacceptable. Individuals are isolated for failures. Mistakes are punished.
Re-design and Modeling	**Analysis**	OSV performance is predicted. Functional analysis complete. Team shares understanding fluently.	OSV performance data is analyzed. Functional analysis begun. Rudimentary understanding.	OSV has no data analysis. Functional analysis missing. Team lacks analytic understanding.
	Design Iteration	Design flaws are addressed. Design iteration is evident. Performance improves.	Design flaws are known. Design iteration is planned. Performance maintained.	Design flaws are ignored. Design iteration is absent. Performance worsens.

Appendix B: Fall 2022 Rubric Version (Current rubric)

Team Performance Rubric

		Some Sample Evidence for Each Rating	
		High performing teams have members who...	**Poorly functioning teams have members who...**
Team Habits	**Equitable Teamwork**	•Distribute work fairly •Recognize inequity, make an effort to address it •Support individuals in improving low quality work •Are patient and willing to help and teach each other •Value and utilize the strengths of its team members •Are comfortable asking each other for help •Critically reflect on how to improve this team habit	•Contribute only when asked •Produce work that is late or incomplete •Unwilling to do more than the bare minimum •Redo work others have completed
	Productive Discourse	•Speak up, listen, hold respectful discussions •Seek and receive constructive feedback •Come to a consensus on a chosen plan of action after disagreements arise •Actively and respectfully seek to address dissatisfaction with teammates •Critically reflect on how to improve this team habit	•Don't come prepared to discuss questions or problems •Dominate discourse and are close-minded to feedback •Are unwilling to compromise on ideas •Avoid addressing conflicts •Derail productive conversations •Don't share concerns or questions until the last minute
	Communication Tools and Techniques	•Share and seek information from each other •Proactively communicate with instructional staff to share status, seek feedback •Maintain a complete and detailed record of meeting minutes •Critically reflect on how to improve this team habit	•Vaguely or rarely communicate with each other •Do not consult teammates when making decisions •Are unaware of other sub-groups' progress •Do not seek help when needed
	Failure, Resilience, and Learning From Setbacks	•Embrace mistakes and failures as necessary learning opportunities that lead to improvement, demonstrating perseverence •Believe in the team's ability to do excellent work •Encourage each other and celebrate good work •Critically reflect on how to improve this team habit	•Punish others for mistakes •Set unrealistic expectations •Lose motivation when experiencing failure •Try to hide or minimize the impact of a setback
Design Habits	**Calibration and Testing**	•Customize calibration •Collect comprehensive test data •Follow testing plans, adapting the plan in response to feedback	•Don't collect any test data •Change the test parameters to fit the desired results •Fail to research the amount of calibration needed •Fail to test fringe cases
	Well-Constructed Prototype	•Build to exceed design specifications •Assemble components/sub-systems with care, high quality materials, with maintenance in mind •Fix components to the chassis in a secure manner, passing a 45 degree tilt test of the OTV without any components moving •Employ a diversity of techniques that are thoughtfully and appropriately chosen •Construct electrical systems with clean, secure, and organized connections •Construct a high level of components in-house •Create polished final products •May incorporate intentional aesthetics (e.g. light, paint, sounds) •Keep excellent and ongoing documentation (incl. photos) for evidence of a thoughtful, well-constructed prototype	•Minimum effort to meet a milestone •Fail to double check their work fits with the overall design •Fail to verify their assumptions match what other teammates are doing •Build subsystems that fall apart with typical use or handling
	Effective Use of Modeling Techniques	•Revisit and update locomotion modeling and assumptions, including -CG calculations -FBD and EEs -CRR assumptions and calcs -torque calculations -linear speed predictions -turning torque •Revisit and update electronics modeling and assumptions, including -full electrical schematic -actual operating conditions of specific parts chosen -power calculations -estimated battery life calculated	•Fail to update models to reflect as-built status •Fail to investigate why initial calculations were different from reality •Primarily utilize haphazard guess-and-checking for troubleshooting
	Design Iteration	•Address design flaws •Improve the product's performance •Make thoughtful design improvements by using the engineering design process •Keep excellent and ongoing documentation (incl. photos) of design iteration	•Stop working on a sub-system once it appears to meet minimum requirements •Only keep record of successes •Don't document what actions were required to achieve a successful iteration
	Integration Planning and Implementation	•Identify each sub-system's dependencies on other sub-systems •Create a plan for when and how to integrate individual and sub-team tasks •Keep other sub-teams up-to-date on progress and adapt the integration plan as needed •Demonstrate a willingness to adjust roles and assigned tasks as needed	•Assign mostly one-person jobs •Are frequently surprised by the impacts of sub-teams on eachother •Encounter many conflicts when integrating work with other sub-teams

Appendix C: Facilitated Team Performance Reflection Activity

MS5 Team Performance Discussion

Overview

Your team is about to have a discussion about the team habits and design habits listed on the Team Performance Rubric (on the back of this sheet of paper). Focus the discussion on what *the team* has been doing well and what *the team* can improve rather than singling out individuals.

Procedure (starting 5 minutes into class)

[1 min] Designate a person who can be a strong timekeeper. Have each teammate sign up to take the lead on the write ups for 1-2 of the habits in the rubric on the back. Be sure to take notes on the habits you are responsible for writing up!

[2 min] Individually and silently take time to read through all of the statements on the rubric [*links to Rubric*] and circle the particular bullet points that reflect your team. These can be either strong or poor habits (it does not hurt your grade if you circle poor habits, so please be honest).

[2 min] As a team, identify and write down the top three habits and the two that can use the most improvement.

[1 min] Pause and ask a volunteer to read this statement out loud to the team:
"Take a moment to remind yourself that equitable speaking time is one of the key habits of a highly effective team. Consider if you may need to step back and make more space for others, or if you need to lend more of your voice to the conversation."

[18 min] Go through each habit (2 minutes each) and have a frank discussion about how the team has been doing. Consider any of the following to help keep the discussion going:

1) What strategies have helped the team?
2) What approaches could use modification?
3) What new strategies could help the team improve?
4) If a particular habit hasn't really been practiced yet, what can your team do to be proactive now?