Balancing Authenticity with Scaffolding and Adding Alignment: Initial Reform of an FYE Student Team Design Project to Improve Learning and Project Performance Outcomes

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Abstract - **Design projects are a common feature of FYE courses, potentially providing students with early experience with engineering design, analysis, prototyping, and testing, along with key engineering teaming and communications skills. One difficulty that can arise in creating or updating engineering design projects is balancing the amount of scaffolding provided by the instructional team to ensure that projects reach some meaningful level of success while also allowing students to confront an authentic, open problem and manage team working processes. This paper shares goals, methods, and insights from an instructional team's ongoing attempt to implement educational best practices in the context of an FYE design project. The instructional team engaged with the balance between open-ended problems and supported learning in preparing reforms to an existing term-length engineering design project in robotics for FYE students. Ultimately, the instructional team altered mid-term project assessments to more directly reflect the types of challenges present on the final demonstration, incentivized performance of multiple required capabilities simultaneously as opposed to separately, and added additional opportunities to demonstrate prototype capability throughout the term. However, while informal feedback from past and current students was positive, initial results drawn from more than 50 student teams in the first year of implementation suggest that the changes did not increase student's overall performance of design and prototyping work.**

Index Terms – Curricular alignment, Design project, Scaffolding

INTRODUCTION

Engineering design is a common topic in FYE classes [1] and the need to prepare engineers to face design problems [2, 3] and various other open-ended and ill-defined technical challenges [4] is well-documented. Thus, there is a continuing need to refine and improve course offerings that prepare students to face challenging, authentic design projects, ideally prior to capstone design courses. This paper discusses the reform of a FYE design project, attempting to retain the need for students to grapple with authentically unclear requirements through a simulated customer interaction process while also providing more scaffolding of the design and test process through better alignment of project formative and summative assessment. Aims of the reform included increasing the proportion of student teams that accomplished the majority of project goals, increasing the frequency of systems thinking in students, and reducing student concerns and complaints about project assessment.

CONTEXT

The reform effort discussed in this study took place in the context of a challenging project in design, robotics, and programming given to FYE students in their first term of study. The FYE course in question is part of the Honors component of a larger FYE program at a large Midwestern university. Depending on college enrollment, the Honors variant of the FYE course generally serves between 200 and 300 highly prepared and motivated students per year. The project, which is the largest of three predominantly out-of-class projects undertaken during the semester, allows student teams to apply class content in teaming, project management, brainstorming, algorithmic thinking and programming, sensors, data cleaning, and design. The project is intended to be completed over 13 weeks and to demand regular and concerted effort by team members to produce a successful prototype.

The project requires the development of an autonomous robot able to 1) follow a line, 2) surmount obstacles along the line, 3) locate and lift containers placed along the line, 4) identify which of three weight classes the container fits into, 5) transport the bin to one of three drop-off locations depending on the weight class, 6) place the container inside a given perimeter and disengage from the bin, and 7) continue this procedure until all bins have been transported to the designated drop-off sites. The robots are constructed using LEGO NXT components from large standardized kits issued to each team. To enforce mechanical complexity in the design of the robot, no wheels, treads, or facsimiles thereof are permitted; no part of the robot with a 360 degree rotating motion is permitted to contact the ground. Students are limited to the contents of the kits with the exception of parts they 3D print for themselves, which allows teams so inclined to employ CAD skills also developed by the class.

A key goal of this project, from the perspective of course faculty, is to move students away from the belief that an engineer will always have all required information needed to accomplish a task available. Many students have prior experience in FIRST robotics or similar programs where the engineering task, along with the metrics for success, are clearly and completely defined. As there exists the previously discussed need to prepare students to face open-ended problems, it is intended for the project to maintain a high burden on students in making sense of the challenge for themselves, and also to limit design processes with excessive reliance on trial-and-error.

One feature of the project contributing to this goal is simulated customer interactions. Examinations of design processes almost always stress the importance of understanding the design context and needs through customer interaction [5, 6], and adding a simulated element of customer interaction to this project is seen as enhancing authenticity and preparing students to face similar situations with non-simulated customers in the future. Without the simulated customer interaction, it is deliberately impossible to understand the required specifications of the robot and the exact nature of the tasks that must be completed. For instance, the means by which different bin drop-off sites can be identified are entirely absent from the initial project description. In the past, teams have arrived at the final demonstration never having contemplated how this task was to be accomplished. In the simulated customer interactions, individual teams have several opportunities to present pre-prepared questions to the teaching team. Incoming questions are matched with one of several hundred pre-prepared answers. Questions lacking in insight or appropriateness are usually matched with unhelpful responses. Teams are not allowed to discuss the information they receive with other students.

Another technique used to keep the problem open-ended and limit students' ability to employ trial-and-error instead of deliberate design and testing is not to permit any students to see the printed paper 'track' or any of the components (small bins, obstacles, etc.) used by the final demonstration until the final demonstration event. Students are allowed and encouraged to create their own test tracks and other items based on their understanding of the required specifications, but nothing is confirmed or denied about the nature of these items except through the simulated customer interactions and the limited amount of information disclosed in the initial project description. This step is seen as important to motivate students to think about what they know and what they need to find out, rather than permitting them to simply perceive the reality of the requirements and react to it.

Based on the need to conceal authentic test materials from teams' view, mid-term assessments of the project have been limited in their ability to assess core competencies of the robot. Students received written feedback from the teaching team on their mandatory design notebooks at several points throughout the term and participated in two small initial demonstrations of their robot. The initial robot demonstrations were deliberately constructed to require students to face problems with some similarities to aspects of the final demonstration, but not all aspects and with only moderate fidelity. The philosophy of these demonstrations might be articulable as 'if you are thinking about the kinds of things you need to think about to be ready for the final demonstration, the tasks of this demonstration should be doable'. For instance, in the final demonstration the robot must be able to turn in order to follow the curved line of the course. Thus, one of the early demonstration tasks involved being able to turn the robot to a precise angle from an initial heading, demonstrating both turning capability and controllability. Similarly, the ability to detect a black line on the ground is critical to the ability to follow such lines in the final demonstration, but instead of tasking students with line following, the early demonstrations might ask them to start the robot walking forward and to stop it after passing over a given number of lines of varying width.

However, over time several concerns arose about the initial demonstrations. First, students consistently complained that they spent time optimizing and perfecting capabilities that may not have been necessary for their final designs. Students interested in earning the highest quantity of points would alter fundamental aspects of their robot, such as walking and turning mechanisms, and write elaborate additional codes targeting high performance on specific aspects of the initial demonstrations. For instance, a robot might be modified to allow fine control over heading angle at the expense of the ability to surmount obstacles, with the former capability assessed formatively and the latter, summatively. Teams dedicating large amounts of effort to early challenges could find themselves with a robot lacking key functionality and frequently reported starting over from scratch late in the term.

These the student complaints, while potentially actionable in themselves, were seen by course faculty to primarily reflect poor curricular alignment between formative and summative assessment. Discussions of formative and summative assessment are available elsewhere, but in short, formative assessment provides students with feedback as to the current state of their learning or performance, with the goal of allowing them to subsequently work to better it. Summative assessment is essentially not about assisting learning, but simply evaluating how much of it has occurred. Curricular alignment [7] is present when course learning outcomes, pedagogies, and assessments are focused on the same learning goals. Curricular alignment requires that formative and summative assessments be carefully targeted to assess the same things, so that learning from the formative assessment is applied to the summative assessment. The classic example of this is ensuring that homework assignments match the contents of exams.

In this case, the initial demonstration tasks given to students to prepare for their final evaluation were related, but at a level of fidelity perhaps insufficient to be fair, especially to younger students in FYE.

Second, and potentially partially due to the issues of curricular alignment already identified, team success rates on the final demonstration of the project were lower than desired. A few teams would arrive to the final demonstration with robots clearly incapable of discharging even basic functionality such as linear motion without structural failure. Very few teams (5 of 68 in 2013) created robots capable of performing all key portions of the final demonstration. Some percentage of the low success rate was and is clearly due to students applying inadequate effort to the project across the term and leaving too much project work to the last minute. Additionally, a high level of challenge is desired for the Honors students. However, room was seen to better scaffold and support a performance in the final demonstration.

Finally, feedback from our industrial contacts (agreements with a firm heavily involved with robotics provides the course with industry observers who attend the final demonstrations and discuss their findings with students in the subsequent class) suggested that students were approaching their robots as an amalgamation of independent sub-systems rather than a necessarily integrated whole. Any changes made to the project that could motivate and support students' use of a systems perspective in their design were seen as desirable. This suggestion mirrors others made by industry [8, 9] and aligns with ABET criterion C [10]. Changes to our formative assessment to place more emphasis on the integration of components into systems were desired.

METHODS – CLASS REFORM

Reforms to the project were made to address the issues identified in the previous section. The goals of the reforms were to improve curricular alignment and incentivize systems thinking, ideally leading to fewer complaints about alignment. Expected secondary effects of the changes included smaller losses in enthusiasm for the course and its materials and increased performance on the final demonstration. The following changes were made to the project.

First, the initial demonstration tasks were altered to more closely and comprehensively align with the final demonstration, while retaining the obfuscation of exact performance requirements. Six new tasks were created to allow students to demonstrate all major features of the robot, including motion, line following, bin pickup and dropoff, bin ID, sensing the dropoff location, and surmounting obstacles. Extended thought was given to designing performance tasks that required students to demonstrate core competencies of the robot without giving away the nature of the exact requirements or forcing students to design to requirements that did not match overall project requirements. The idea underlying the majority of tasks was to put the burden on students to articulate the challenge that they faced based on their understanding of project requirements. Thus, for line following, numerous lines were printed on numerous tracks. Teams could select any line they pleased and, upon following it for a set length, be awarded credit. Similarly, for bin pickup, teams had to provide their own test bins. The instructional team permitted the use of bins that did not approximate those used on the final demonstration. For surmounting obstacles, a selection of obstacles of different sizes and types were provided, and teams had to select one obstacle from each of three general size categories to traverse. Teams selecting lines, obstacles, or bins more difficult than required would face more difficult demonstration tasks. The six initial demonstrations were each named a 'Presentation of Competency', or PoC. The name Presentation of Competency was selected to give the impression that team robots should be competent at the task prior to arriving at the event and discourage tinkering, though all tasks were time limited to two minutes each. All PoC tasks were given at four different times throughout the term to allow teams to redesign their robots as their capabilities and understanding of the required performance improved.

Second, the scoring of the initial demonstration tasks was altered to emphasize and incentivize the production of robots successfully integrating multiple subsystems, capable of performing multiple tasks without reconfiguration. Up to 12 points out of a PoC rubric value of 20 could be earned by displaying multiple competencies at the same PoC event with the same robot, as opposed to attempting to demonstrate different competencies at different assessment events with robots tuned to do a smaller number of things.

Third, to focus student attention on the need to understand performance requirements, much greater emphasis and feedback was provided on specifications prepared by student teams. For each PoC event, teams had to submit detailed specifications for their robot listing all performance specifications for each individual PoC task, including current and target values. Rigorous review of and feedback on the specifications was provided by specially trained and prepared undergraduate TA's overseen by a graduate TA. Teams were given an opportunity to refine the submitted specifications each time. Teams who failed to produce appropriate and complete engineering specifications for a given PoC task were allowed to test their robot on that task, but could not receive credit for accomplishing it. This element of the reform was an important accompaniment to allowing teams to select from a variety of PoC test conditions that only sometimes approximated the final demonstration requirements.

METHODS – ASSESSMENT

Improved performance on the final project demonstration was the main easily measurable outcome of the project. Therefore, changes to the final project demonstration task were minimized between academic years to promote comparability of results.

However, while surmounting an obstacle was always one of the requirements for the final demonstration, it previously had not been assigned points directly (failure to surmount the obstacle would lead to loss of opportunity to earn points in later stages of the demonstration) and historically the first obstacle occurred about halfway through the final demonstration and was attempted by a minority of teams. Between 2013 and 2014, an obstacle smaller than the specified maximum obstacle size was added early in the course and assigned points directly to ensure that more teams had the chance to demonstrate their robot's ability to surmount an obstacle, a capability deeply tied to the backstory and motivation for the design project. Some effects on scoring due to this change were anticipated, and are accounted for in the results section.

Two other minor changes occurred between the 2013 and 2014 robot projects. The final demonstration was conducted in a different venue in 2013 and 2014 due to differences in available spaces large enough to accommodate the event. Differences in venue are potentially relevant to the event as they may change the angle and quantity of ambient light, which may make it easier or more difficult for student robots without robust algorithms to line-follow with light sensors. Any effects from this change are difficult to quantify but were expected to be limited. Finally, the NXT kits available to teams were repackaged into more organized and durable containers, but as no meaningful changes to kit contents occurred between 2013 and 2014 this was not anticipated to affect results.

Teams' robots were evaluated on their capacity to perform discrete stages of the overall final demonstration challenge but were not permitted to advance to later stages without completion of the earlier ones. For instance, a robot unable to follow the line would not reach the bin pickup zone, and a robot unable to pick up the bin will not proceed to the bin drop-off zones. However, a team that picked up a bin but identified it incorrectly would be allowed to attempt drop-off in the zone corresponding to the type of bin the robot incorrectly identified. Teams were allowed to reset and restart their robot as many times as desired in both years, subject to an overall demonstration time limit of ten minutes.

Teams also demonstrated discrete competencies on separate challenges at the final demonstration event. In 2013 these separate tracks were in some ways similar to the POC's, while in 2014 the POC tracks were used for this purpose. Items such as bin pickup and drop-off were tested without the need to simultaneously demonstrate other ideally integrated competencies such as line following, allowing student teams to receive credit for functioning subsystems that did not amount to a functional whole. The results from the 2013 discrete competency tests are not directly comparable to the PoC results and are not discussed further in this paper. The success of student teams on various PoC challenges was determined at each PoC event.

Some potential confounding factors exist in this study. First, different student cohorts, in different teams, participated each year. While the number of student teams is substantial in each case (68 in 2013 and 50 in 2014) and no differences in overall student preparation characteristics were expected (students are recruited based on characteristics that were not changed between sampled years) it is possible that different cohorts had different overall levels of academic preparation that could affect project performance. Second, one course faculty member departed and was replaced over the sampled years. Third, while the course content relating to teaming, design, and other related topics was not radically altered, small changes in presentation did occur. For these reasons, the data collected on final demonstration performance are quasi-experimental in nature and the changes in course design cannot be conclusively connected with the outcomes observed.

RESULTS

It can be seen in Table I that four of the six PoC tasks were accomplished by 80% or more of teams during at least one of the four PoC events. Recall that for the line following and obstacle clearance challenges that student teams selected their own lines and obstacles from a collection made available to them, some of which were substantially more difficult than required for success on the final demonstration track.

TABLE I
POC TASK PERFORMANCE

Task	Successes (of 50)	Success Rate
Walking Speed	49	98.0%
Line Following	34	68.0%
Obstacle Clearance	23	46.0%
Sensing Drop-off point	49	98.0%
Bin Pickup + Drop-off	40	80.0%
Bin ID	42	84.0%

It can be seen in Table II that on average, teams earned a little more than 8 of the 12 possible points given for successful integration of tasks, corresponding to the demonstration of an average of slightly higher than four competencies at the same PoC event. This average is drawn from the highest value that each team earned at any of the four PoC events, rather than an overall average across all events. Most teams displayed the majority of their competencies at the same PoC event at some point during the term. Success on PoC tasks generally increased across the term, as would be expected.

It should be noted that displaying four simultaneous capabilities (corresponding with a score of 8 integration points out of an overall score of 20) earned 'full' credit by the rubric for this event, while simultaneously displaying five or six competencies earned bonus points, up to a maximum of four, corresponding with a total possible score of 24 points. Percentages out of scores of 20 and 24 are displayed in Table II for convenience. Some teams may have chosen not to pursue the bonus points once four tasks had been completed.

TABLE II
POC OVERALL PERFORMANCE

PoC Overall Performance	Score	Percentage
Average Integration Points (of 12)	8.56	71.3%
Average Total Score (of 20)	17.92	89.6%
Average Total Score (of 24)	17.92	74.7%

The results for discrete aspects of the final demonstration are shown by count and success rate in Table III and Table IV, respectively. In Table III, the '2013 (50 Teams)' column applies the 2013 success rates to the 2014 number of teams to present a scaled 2013 count that can be compared to the 2014 count directly, as the overall number of teams was substantially different between years. A total of 68 teams participated in 2013 and 50 teams participated in 2014. It can be observed that success counts and rates were generally down slightly for 2014 versus 2013. In Table IV, the success rates shown are for all teams, not just teams that reached and attempted that stage of the demonstration. Most teams did not attempt the later stages of the demonstration and were therefore marked as unsuccessful.

TABLE III
FINAL DEMONSTRATION PERFORMANCE BY COUNT

Task	2013 Count	2013 (50 Teams)	2014 Count
Fork	66	48.5	47
Obstacle	NA	NA	43
Stop @ Load 1	37	27.2	25
Pick Up Bin 1	29	21.3	17
ID Bin 1	17	12.5	12
Drop Bin 1	13	9.6	7
Bin Position 1	6	4.4	2
Pick Up Bin 2	5	3.7	2
ID Bin 2	2	1.5	2
Drop Bin 2	3	2.2	0
Bin Position 2	1	0.7	0
Pick Up Bin 3	1	0.7	0
ID Bin 3	1	0.7	0

TABLE IV
FINAL DEMONSTRATION PERFORMANCE BY RATE

Task	2013 Rate	2014 Rate	Rate Change
Fork	97.1%	94.0%	-3.1%
Obstacle	NA	86.0%	NA
Stop @ Load 1	54.4% (50.1)	50.0%	-4.4%
Pick Up Bin 1	42.6% (39.2)	34.0%	-8.6%
ID Bin 1	25.0% (23.0)	24.0%	-1.0%
Drop Bin 1	19.1% (17.6)	14.0%	-5.1%
Bin Pos 1	8.8% (8.1)	4.0%	-4.8%
Pick Up Bin 2	7.4% (6.8)	4.0%	-3.4%
ID Bin 2	2.9% (2.7)	4.0%	1.1%
Drop Bin 2	4.4% (4.1)	0.0%	-4.4%
Bin Pos 2	1.5% (1.4)	0.0%	-1.5%
Pick Up Bin 3	1.5% (1.4)	0.0%	-1.5%
ID Bin 3	1.5% (1.4)	0.0%	-1.5%

The values in parentheses in the '2013 Rate' column of Table IV reflect an attempt to account for the addition of the obstacle to the main course in 2014. As 8% of 2014 teams did not pass the additional, early obstacle, and were thus prevented from attempting to complete later stages of the demonstration, a factor of 0.92 was applied to all 2013 success rates subsequent to the location of the obstacle to estimate the success rate of subsequent stages if the obstacle had been in place in 2013. These values appear in parentheses. It can be seen that even with the obstacle accounted for, success rates tended to be lower in 2014 than in 2013.

Relating to the requirement of presenting specifications prior to being allowed to earn PoC points, it was observed over the course of the term that student-submitted specifications improved dramatically and that many conversations about the nature of appropriate engineering specifications were needed and supplied. Course faculty were surprised at the low quality of the specifications initially submitted as students had demonstrated no trouble writing specifications in class exercises. The difference between the relatively hypothetical class exercises and the utterly real robot specifications appeared to be significant to students. Based on the much larger quantity of discussion in this area versus prior years and the improvements over the term, course faculty are confident that this reform lead to substantial increases in student consideration of the specification of their robots, and by extension likely lead students to more deeply consider what performance was required for the final demonstration. However, it is difficult to quantify the effects of this aspect of the intervention.

Feedback from past and current students on the changes made was positive overall. As all undergraduate TA's for the class are class alumni, feedback was sought in the planning stages, execution, and the close of the project from the roughly 20 undergraduate TA's employed. Strong consensus was present that the changes better related the initial demonstrations with the final demonstration and represented a positive change in the course that addressed concerns about the project they retained from their time as students.

Current students were asked for feedback and improvement ideas at the close of the project during a class reflection and discussion period. Such reflection and discussion periods are used at the close of all major and several smaller class projects. The most noteworthy student concern was that, for some PoC tasks, the standards for success were higher than those for the final demonstration. As previously noted, this was done to avoid disclosing the exact specifications of the final demonstration outside of the simulated customer interaction process. Teams that were aware of the exact specifications of the final demonstration and designed to them felt penalized, specifically in the PoC task relating to surmounting obstacles. However, teams overall felt the PoC process was reasonable and fair and had few suggestions or complaints.

DISCUSSION

Course faculty expected that the expanded and better-aligned formative assessment provided by the PoC process would better prepare teams to meet the challenges of the final demonstration, resulting in higher scores. Acceptable performance on PoC tasks seemed to indicate that teams would be well-prepared for the final demonstration. The results clearly show that this was not the case. Overall performance on the final demonstration decreased in all tasks accomplished by at least two teams. The consistency in achievement of equal or lesser performance post-intervention, even accounting for the effects of the addition of the early obstacle, strongly suggest that that the intervention did not increase performance on the final demonstration course year-to-year and may have reduced it. The sole post-intervention increase is likely not meaningful as no clear features distinguishing it from lower performance on tasks surrounding it exist and the number of teams accomplishing it in either academic year is small.

Reflection by course faculty on the reasons that the intervention failed to improve performance identified three plausible rationales. First, student teams were observed to place great emphasis on accomplishing the PoC tasks, even on the final demonstration day. Teams were heard justifying or explaining poor final demonstration performance by stating that they had focused their efforts on accomplishing the PoC's, despite the fact that the abilities required for the PoC's and the main track had been made nearly identical and incentives for systems integration had been added. The PoC results show that the majority of teams produced robots capable of accomplishing the majority of final demonstration tasks, but this success did not translate to the main course where an integration of capabilities was required. This suggests that the 'integration' scoring of the PoC's may not have been sufficient to focus student attention on the need to integrate robot capabilities for use on the final demonstration track. A consensus of course faculty and TA's found that student focus on the PoC's at the expense of preparing for the final demonstration is the most likely reason that the reformed project did not improve final demonstration performance.

A second possible explanation for the steady-to-lower performance observed is inter-cohort differences in ability in constituent skills required for the robotics project, specifically in programming. While average programming homework grades were slightly (0.4 points) higher for the fall 2014 cohort, programming quiz grades were moderately less (2.8 points). Additionally, the fall 2014 cohort gave the impression across course faculty and TA's as being less fluent in programming tasks than the previous cohort. This may have simply been a willingness to seek more help, thus leading to the impression of needing more help, but should be acknowledged as potentially contributing to the measured decrease in performance. It is possible that the 2014 cohort struggled more with programming their robots and that this struggle is reflected in the performance measurements.

A third possible explanation is the differences in ambient light between the final demonstration venue used in 2013 and 2014. Though student teams were informed of the venue ahead of time and permitted to engage in any testing or calibration they desired relating to the lighting in both venues in both years, the 2013 venue appeared to have slightly more uniform lighting that may have been beneficial to a subset of teams without robust line-following algorithms. There exists a chance that the results were influenced by the difference in light, with any such effect expected to reduce the 2014 results relative to the 2013 results.

FUTURE WORKS

Continued reform of the project is suggested by the results. The observed student focus on PoC's at the expense of the final demonstration will be addressed through several means. First, PoC scoring will be reduced in value relative to the final demonstration. The reduction in point value is intended to emphasize that the PoC's constitute formative assessment and are not as important as the final demonstration. The final demonstration will rise from roughly equal in value with the PoC's to approximately three times more valuable.

Second, the number of PoC events will be reduced from four to two, and no PoC will occur on the final demonstration day. The final PoC event will occur several weeks prior to the final demonstration. By reducing the number of PoC events and limiting them to earlier in the term, it is intended that a clear line between the PoC's and the final demonstration will be drawn, and that student attention will be focused on the final demonstration for the last several weeks of the course.

Third, class discussions about the project throughout the term will pointedly emphasize the role of PoC's as formative assessment and suggest that teams plan for the period after the final PoC event to contain primarily systems integration work, rather than continued development of core functionality. Increased verbal emphasis on systems integration is unlikely to be counterproductive.

Fourth and finally, efforts outside the scope of the reform of this particular project to increase in-class engagement and moderately reduce the quantity of work required outside of the class may cause some teams to allocate additional effort towards project success, though it is expected that many students will allocate any time saved towards non-class activities. It is intended that the final demonstration tasks remain unchanged in the upcoming year, and course faculty eagerly await next year's results as an indication of whether these further reforms further course goals.

Additionally, the PoC task relating to surmounting obstacles will be adjusted so that teams with performance specifications reflecting the final demonstration requirements are more likely to succeed. This task proved to be by far the most challenging as presently configured and based on student feedback and the performance results gathered requires some modification.

CONCLUSIONS

While the reforms enacted so far have not achieved goals relating to increased project performance, they did substantially address and reduce student complaints about the alignment of formative and summative project assessments while also preserving an emphasis on authentic, open-ended project requirements. It is expected that the increased quantity of feedback and accountability students received on their performance specifications resulted in an enhanced student capability to produce appropriate performance specifications. The goals, methods, and considerations of the overall project and the proposed reforms may be informative to other engineering educators, especially in FYE. The identified future works present plausible paths to strengthening the tested reforms.

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