# A Multi-level Approach to Project Team-based Learning: Effect of Charter Use on Engineering Students' Project Team Performance


Jiawei Li, Mounika Yallamandhala, Preeti Nain*, Sinem Mollaoglu, Kenneth Frank, Annick Anctil, Kristen Cetin

**Jiawei Li,** PhD candidate, Department of Counseling, Educational Psychology & Special Education, College of Education, Michigan State University, East Lansing, Michigan, USA, 48823, lijiawei@msu.edu

**Mounika Yallamandhala**, Research Assistant, School of Planning, Design and Construction, Michigan State University, East Lansing, Michigan, USA, 48823, yallaman@msu.edu

**Preeti Nain**, Post-doctorate, Civil and Environmental Engineering, Michigan State University, East Lansing, Michigan, USA, 48823, nainpre1@msu.edu

**Sinem Mollaoglu**, Professor, School of Planning, Design and Construction, Michigan State University, East Lansing, Michigan, USA, 48823, sinemm@msu.edu

**Kenneth A. Frank**, Michigan State Foundation Research Professor of Sociometrics, College of Education, Michigan State University, East Lansing, Michigan, USA, 48823, kenfrank@msu.edu

**Annick Anctil,** Associate Professor, Civil and Environmental Engineering, Michigan State University, East Lansing, Michigan, USA, 48823, anctilan@msu.edu

**Kristen Cetin,** Associate Professor, Civil and Environmental Engineering, Michigan State University, East Lansing, Michigan, USA, 48823, cetinkri@msu.edu

## Abstract

**Background:** Exposure to teamwork and collaborative projects in engineering education is crucial for preparing students for engineering jobs. Several universities are adopting Project-Team Based Learning (PBL) to deliver work-ready graduates required in technically complex inter-organizational project environments. However, the use and levels of adoption of project management techniques and tools (e.g., charters) and the multi-level nature of team science for engineering education and workforce development are not well-investigated in the literature.

**Purpose:** This study investigates whether the level of compliance with using a project charter at individual and team levels throughout project delivery enhances team performance (i.e., group potency, team viability, and team cohesion) in engineering education settings, such as classroom and extracurricular projects.

**Design/Method**: We examined relationships using multilevel modeling (MLM), which means examining teams at both student (individuals) and team levels (groups). We utilized qualitative insights to guide model specification and interpretation.

**Results:** The findings revealed that consistent use of project charters, assessed through perceived compliance, was linked to significant improvements in group potency, team viability, and team cohesion. Compliance effects were observed at both individual and team levels, with generally comparable contributions to group potency, team viability, and team cohesion. Furthermore, the link between individual compliance and performance tended to be weaker in teams with high performance. Our MLM analyses also revealed that classroom teams scored lower at baseline on group potency, team viability, and team cohesion compared to extracurricular project teams. Future studies should delve deeper into these differences by examining factors such as work environment, modality of education (e.g., classroom versus extracurricular, for pay versus for

grade or experience), team composition (e.g., level of education, experience, and skill heterogeneity), project nature, and prior relationships among team members.

**Keywords**

Engineering education; Multilevel analysis; Project team-based learning; Project Charter; Team compliance

# 1. Introduction

The traditional curricula-based methods of engineering education are becoming less effective as the profession evolves. Project-Team Based Learning (PBL) is becoming more popular in fostering both technical and professional skills in engineering students (Mandal, 2018a). Traditional engineering education and PBL vary in terms of delivery and evaluation. Several universities have adopted PBL approaches supported by laboratory studies and industry-focused projects in the US to deliver work-ready graduates required in technically complex inter-organizational project environments (Shah & Gillen, 2023). With PBL, students learn by doing, which helps them apply theoretical knowledge to real-world problems (Seidel & Godfrey, 2005). Exposure to teamwork and collaborative projects in engineering education is crucial for preparing students for engineering jobs. With respect to sustainable construction engineering projects, where energy and materials utilization needs lower environmental impacts, timely project completion is especially challenging (Hwang & Ng, 2013), thus the need for strategic use of project management tools.

While PBL offers significant educational benefits, it also introduces challenges similar to project team environments of the industry, particularly in terms of resource allocation, coordination, monitoring, and assessment. To overcome such challenges, charters, as project management tools, can be adopted in both education and workforce settings (Courtright et al., 2017). Charters provide a formal guiding platform for self-monitoring team members' behaviors and progress toward achieving team goals. Project charters are best utilized when co-created by team members collaboratively and can help create milestones, divide the responsibilities among team members, set up communication and conflict resolution terms sand means (Mandal, 2018b); and eventually help improve coordination among team members, prioritize tasks upfront, and reduce ambiguities within a project team (Kirkpatrick et al., 2022). Project charters have been extensively used in engineering education (Johnson et al., 2022a; Mandal, 2018a), but the impact of their systematic use is yet to be explored. Understanding the influence of systematic use of project charter on team performance and dynamics can guide engineering project team formations and project team interactions, eventually leading to improved project outcomes. Such a tool can especially be helpful when time pressure is high in a project team, deliverables are complex and innovative, and/or team members lack an established and/or shared baseline for collaborative work.

Most studies on PBL have primarily focused on individual-level factors that influence performance and overall project success. However, there is a noticeable lack of attention to team-level factors and interactions between individual and team-level factors in PBL and student-team research. Multilevel analysis is especially valuable in fields like education, psychology, and organizational research, where it is crucial to understand the complex interplay between individual and contextual factors to advance both theory and practice (Ganotice Jr et al., 2022). Therefore, further research is needed to examine both team/group-level and individual/student-level factors to offer a more comprehensive understanding of the facilitators and barriers affecting engineering project outcomes, such as task completion, team effectiveness, and overall team performance. Click or tap here to enter text.

# 2. Literature Review

## 2.1 Project team-based learning

The shift in engineering education from traditional discipline-based curricula to more integrated, project-based, and team-based learning approaches is driven by the evolving needs of the engineering profession, which now demands cross-disciplinary knowledge and skills due to the increasing complexity of technological systems (Seidel & Godfrey, 2005). Many studies reported that PBL effectively develops non-technical and technical skills among engineering graduates. PBL is more suitable for engineering education because it provides students with practical, hands-on experience that better prepares them for industry roles (Noordin et al., 2011). A study by Kwan (2016) evaluating the effectiveness of PBL in civil engineering education concluded that PBL enriched students' learning experience by enabling them to integrate theory into practice, understand industry design processes, and acquire practical skills (Kwan, 2016).

Even though PBL and education for sustainable development share common learning principles, their practice presents challenges in fully integrating sustainability due to constraints such as balancing interdisciplinary knowledge and offering insights into potential improvements for curriculum design (Guerra, 2017). Fishlock et al. (2023) addressed the growing issue of e-waste by adopting the PBL pedagogy in a pilot study to train undergraduate design engineers in sustainable product design. They observed the effectiveness of integrating PBL into first-year engineering education students with high student engagement and intentions to implement sustainable design practices in the future (Fishlock et al., 2023). A study by Zhang (2023) adopts PBL in engineering mechanics courses to enhance student engagement and learning outcomes. Results indicate that the intervention positively impacted exam scores overall, with female students exhibiting higher participation rates and greater improvement, suggesting the importance of offering flexible, learner-centered approaches like PBL to accommodate diverse learning preferences (Zhang, 2023). Another recent study examining the effectiveness of PBL on civil engineering students shows that despite its time-consuming nature, students perceive PBL as effective, relevant, and motivating for promoting independent learning (Azam et al., 2024). However, one common challenge observed in PBL is that the students indulge in various course assignments simultaneously and often fail to complete the project tasks on time. The post-pandemic dynamics of virtuality and uncertainty have introduced new coordination challenges for all teams, especially for higher education student teams working on real-world sustainability engineering projects. In addition to team member characteristics—such as academic background, prior experience with similar projects and organizations, and cultural background—project management tools and interventions also play a crucial role when teams are required to work on multiple projects across various teams.

**2.2 Project charter as a project management tool and Team performance**

Most of the failures in engineering projects are due to poor planning and a lack of project management skills (Okereke, 2017). Struggles in student and workforce development settings that facilitate PBL are no exception. Pereira and Diaz, (2021) address procrastination among university students by utilizing GanttBot, a Telegram chatbot resulting in a significant reduction in overdue days compared to the control group by integrating alerts, advice, automatic rescheduling, motivational messages, and references to previous projects to aid students in managing their time effectively and meeting deadlines (Pereira & Díaz, 2021). Project charters take the time management aspects of project management and add co-creation of team communication and conflict resolution elements as well as work division and resource allocation layers and provide a unique platform for improving team performance within engineering project-based education. Beyond simple guidelines, they provide a structured framework that helps team formation by setting clear expectations, aligning efforts, and fostering mutual accountability (Johnson et al., 2022b).

Team formation can be crucial for team performance (Cox & Bobrowski, 2000). While the investigations on the importance of project performance increased, team performance and its relationship with project performance is not emphasized. Given that team members' coordination and functioning develop along with the project, their performance is a solid foundation for project performance (Mathieu & Rapp, 2009). Setting baseline rules can be critical to team performance. Generally, project management tools, like project charters, are provided to teams to foster systematic planning against deliverables (Hackman & Katz, 2010). A project charter can motivate team members to schedule their tasks and interim milestones, which, in turn, paces their activities in coherence with scheduled tasks and milestones. Moreover, consistent use of a project charter can help teams manage conflicts well (Johnson et al., 2022). Although sparse and disparate, previous research on implementing project charters in PBL for sustainability engineering suggests that project charter improves the coordination among team members and results in the timely completion of tasks (Mandal, 2018) (Siddiquei et al., 2022). However, most of these studies focused on investigating the impact of project charter use on team cohesion or project performance, but limited research investigated the impact of its systematic use.

### 2.3 Individuals and Groups: Multilevel Perspective of Team Science

Project teams in civil engineering inherently operate across multiple levels, with individual members working together to achieve shared goals. This multilevel nature is essential to team sciences, as outcomes are shaped not only by characteristics at each level but also by their interactions (Klein & Kozlowski, 2000). Research has shown that individual performance or scores are influenced by the team to which a student belongs, meaning their performance is not independent of the group (Strijbos et al., 2007). However, there is limited research on the effects of factors at multiple levels within the context of civil engineering project teams working on real-world projects. Multilevel models (MLM) account for the nesting of team members within teams in calculating standard errors and allow for a broader set of research questions, including those at the individual and team levels as well as the cross of the two. (Ganotice Jr et al., 2022; Ko & Law, 2024; Raudenbush & Bryk, 2002). Given MLM's focus on nested data structures (such as individuals within teams), PBL studies in construction and engineering should incorporate MLM to better account for these complexities.

## 3. Point of Departure

Reviewing the literature revealed that various assessment methods exist to improve engineering students' performance and teamwork (Aaron et al., 2014; Hunsaker et al., 2011; Johnson et al., 2022b). While the relevance of these methods is clear, there is limited investigation of temporal changes related to student performance in sustainability engineering projects at multiple levels (i.e., individual versus team-level). Previous research investigates the impacts of project charter use rather than the impacts of its consistent exposure on team and project performance (Johnson et al., 2022b; Mandal, 2018b). Moreover, PBL in engineering education can be done via classroom projects or extracurricular activities like outreach or engagement projects to train engineering graduates for workforce development. An overarching investigation on studying the impact of consistent use of project charters in PBL applied to AEC projects can provide useful insights into the most important factors that impact team and project performance. To be precise, the literature fails to evaluate the effectiveness of using (and not just exposure to) a project charter throughout project delivery on team performance, especially in the context of engineering education and workforce development.

To address this gap, this study investigates whether the level of compliance with project charter use at individual and team levels throughout project delivery enhances team performance (i.e., group potency, team viability, and team cohesion) in engineering education settings, such as classroom and extracurricular projects. We examined these relationships using multilevel modeling to examine both student (individuals) and team levels (groups). Specifically, this study addresses the following research questions (RQs):

**RQ1:** Does using a project charter throughout project delivery, as measured by perceived compliance, enhance team performance (i.e., group potency, team viability, and team cohesion)?

**RQ2:** Are there impacts of perceived compliance at individual and team levels on team performance?

## 4. Methodology

### 4.1 Scope

The study focuses on classroom and extracurricular student engineering projects in a higher education institution setting in the Midwest US. The classroom project is an integral part of Sustainable Civil and Environmental Engineering Systems, an interdepartmental course for juniors or seniors in Applied Engineering Sciences, Civil Engineering, Environmental Engineering, or minoring in Energy. In this classroom project, students engaged in evaluating the real-world challenges related to the environmental impacts of transportation. Utilizing multi-criterion decision analysis, they assessed economic, social and environmental criteria to develop sustainable solutions.

The extracurricular project refers to the industrial assessments conducted year-round by Industrial Assessment Centers (IAC) at higher education institutions across the US (*MSU-IAC*, 2024). These centers offer no-cost technical assessments to small and medium-sized manufacturers, supporting their clean energy transition by helping them save energy, improve productivity, and reduce waste. Most students participating are Environmental Engineering and Civil Engineering majors who receive specialized IAC training to conduct these assessments. Students often remain involved with IAC over multiple semesters, taking on roles that include both leading and participating in the assessments. Both the classroom and the extracurricular projects span over eight to nine weeks and are conducted by teams of three to six members.

A project charter (MSU, 2024), as a project management tool, was provided to both classroom and extracurricular project teams in the above-mentioned settings, along with a training video (Training Video, 2024) to assist students with its collaborative use. The charter includes sections on project definition and team composition, vision, milestones, roles and responsibilities, and preferred communication methods and conflict resolution strategies (Mollaoglu et al., n.d.).

### 4.2 Data Collection and Measures

Our research team collected data for over two years (between the Summer of 2022 and the Spring of 2024), targeting two different offerings of the course in the fall and spring semesters for classroom project teams and the year around operations of the IAC for extracurricular project teams (i.e., that spiked in number of projects during summer and fall semesters). At the beginning of each semester, our research team presented to the target populations explaining the study's scope and the Institutional Review Board (IRB) process emphasizing voluntary participation. Incentives were provided to encourage participation, and a survey was distributed at the end of the recruitment presentation to obtain students' consent to participate.

Data was collected electronically using Qualtrics, an online survey tool, with four surveys administered at the beginning, during, and after completion of the project. These surveys included questions on participants' demographics, perceived team performance, and perceived level of compliance with charter use.

For **team performance**, our study adopted *group potency, team viability*, and *team cohesion* composite measures. Accordingly, the respondents evaluated their perceptions of how their project team performed through survey items using a 4-point Likert scale between 1 (Strongly Disagree) to 4 (Strongly Agree). The composite measures were calculated as explained below. Cronbach's alpha (ranging between 0 and 1) was calculated to assess the reliability of multi-item measure, all exceeding the acceptable threshold of .7 (Mallery & George, 2000). Pearson correlation was used for two-item measures, with all values meeting the large effect size threshold of .5 (Cohen, 2013).

- **Group potency**, defined as the collective belief among group members in their ability to work well together and be effective, was calculated as the mean score of two survey items: "This team can solve any problem it encounters" and "This team can be very productive" (adapted from Guzzo et al., 1993). The Pearson correlation between these two items was .707.
- **Team viability,** defined as specific interpersonal skills essential for effective team participation, was derived by averaging the scores of three survey items: "I really enjoyed being part of this team," "I felt like I got a lot out of being a member of this team," and "I wouldn't hesitate to participate on another task with this same team" (adapted from Tesluk & Mathieu, 1999; i.e., satisfaction and intention to stay). The Cronbach's alpha of these three items was .920.

- **Team cohesion,** defined as the team's shared commitment to the task, was calculated as the average score of three survey items: "My team had a unified vision for what we should do," "My team members contributed to the team's goal," and "My team members were committed to our team's goal", adapted from (Hackman & Katz, 2010) and (MacCoun, 1996). The Cronbach's alpha of these three items was .937.

***Perceived level of Compliance with charter use*** measures the degree to which individual team members perceive compliance with the project charter use during project delivery (Project charter, 2024). We focused on perceived rather than actual implementation because beliefs about compliance often shape behaviors and interactions within teams. When team members perceive themselves as following the charter, it improves collaboration and problem-solving, leading to greater productivity (Herrera et al., 2017). These shared beliefs ultimately enhance project performance by ensuring that everyone understands their roles and how their contributions align with the team's goals. For reliability, Pearson correlation was used as explained above.

- We measured this variable at the ***individual level*** based on the responses to the following two survey items, rated on a 4-point Likert scale between 1 (Strongly Disagree) and 4 (Strongly Agree): "My team filled out our project charter together" and "My team revisited our project charter at regular intervals." The Pearson correlation between these two items was .510.
- ***At the team level*,** an additive model approach was adopted (Chan, 1998), where the average score of compliance from all team members (i.e., **Average Compliance** from here on) was computed to represent overall team compliance with the project charter use.

### 4.3 Data Analysis and Analytic Models

A two-level MLM with full maximum likelihood estimation was employed to investigate the impact of charter use compliance on team performance. Unlike traditional regression methods, MLM accounts for dependencies within clusters by partitioning variance into within-group and between-group components, resulting in more accurate estimates and standard errors that reflect dependencies within groups. This approach allowed for examining effects at individual- (Level 1) and team-level (Level 2), with individuals nested within teams. The analysis used HLM 8.2 software (Raudenbush & Bryk, 2021).

The analysis began with unconditional means models (M0), which did not include any level 1 or level 2 predictors, to quantify baseline variation in the three outcome variables—group potency, team viability, and team cohesion—at both the individual and team levels. These models served as a reference for understanding how variance was distributed across levels. Next, conditional models were specified for each of the three outcome variables. The first set of conditional models (M1) included perceived compliance at the individual level. The second set of conditional models (M2) incorporated the group-mean centered compliance at the individual level and average compliance at the team level, allowing for a comparison of individual perceptions versus team context. The M2 model equations were defined as follows[1]:

***Level 1 (Individual Level):***

$$Y_{ij} = \beta_{0j} + \beta_{1j} * (Compliance_{ij} - \overline{Compliance}_{j}) + r_{ij}$$

[1] Note: All model equations (M0 – M3) can be found in Appendix 1. Unless otherwise specified, Compliance was grand-mean centered.

where $Y_{ij}$ represented the outcome variables (i.e., group potency, team viability, and team cohesion) for individual $i$ in team $j$. The term $Compliance_{ij}$ referred to the perceived compliance score for individual $i$ in team $j$ and $\overline{Compliance}_j$ was the mean perceived compliance for team $j$. Therefore, $Compliance_{ij} - \overline{Compliance}_j$ represents the individual's perceived compliance relative to the team average. For example, for an individual whose compliance score was 3 in a team with mean 2, $Compliance_{ij} - \overline{Compliance}_j$=3-2=1. On the other hand, if the team mean was 1 then $Compliance_{ij} - \overline{Compliance}_j$ would be higher: 3-1=2. Correspondingly, $\beta_{1j}$ was the slope for team-mean centered compliance in team *j,* reflecting the change in the outcome variable for a one-unit increase in individual perceived compliance relative to the team. In that context, $\beta_{0j}$ was the overall intercept for team $j$, indicating the expected value of the outcome variable when the compliance was at its mean for team $j$ and $r_{ij}$ was the residual error for individual $i$ in team *j.*

***Level 2 (Team Level):***

The conditional Level 2 equations were formulated by using the Level 1 intercept and slope as outcomes.

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (\overline{Compliance}_j - \overline{\overline{Compliance}}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

where $\gamma_{00}$ was the intercept – the $\beta_{0j}$ in a team who had average levels of compliance ($\overline{\overline{Compliance}}$ was the grand mean of compliance across all teams); $\gamma_{01}$ was the slope for grand-mean centered average compliance, indicating how much the team's average outcome changed for a one-unit increase in the average compliance; $\gamma_{10}$ was the average estimated effect of individual compliance across all teams; and $u_{0j}$ and $u_{1j}$ were the random effects for team *j.*

Next, scatterplots were generated for each team to explore the relationships between charter use compliance and three team performance outcomes. Examining the scatterplots led to the development of further exploratory research questions and the third set of conditional models (M3) with a focus on the type of project teams in engineering education settings (classroom versus extracurricular).

# 5. Results

## 5.1. Sample Demographics

The target population included 89 teams with a total of 345 members. Of those, 43 teams were from the classroom setting with 195 individuals/team members, and 46 teams were with 21 individuals/150 team members since individuals were assigned to multiple project teams in the extracurricular setting. However, only 49% of participants who provided valid survey responses regarding perceived team charter compliance were included in the analysis, resulting in a final sample size of 52 teams comprising 169 members. Table 1 below shows the sample demographics for the study.

**Table 1. Individual-Level Demographics**

| Variables | | *N* | % |
|---|---|---|---|
| **Gender*** | | | |
| | Male | 88 | 52.1 |
| | Female | 80 | 47.3 |
| **Race*** | | | |
| | White | 126 | 74.6 |
| | Other | 38 | 22.5 |
| **Academic Program** | | | |
| | Environmental Eng | 66 | 39.0 |
| | Civil Eng | 61 | 36.1 |
| | Applied Eng | 33 | 19.5 |
| | Mechanical Eng | 4 | 2.5 |
| | Other | 5 | 2.9 |

| | Variables | *N* | % |
|---|---|---|---|
| **Academic Maturity** | | | |
| | Undergrad | 163 | 96.4 |
| | PhD | 5 | 3.0 |
| | Other | 1 | .6 |
| **Project Team** | | | |
| | Classroom | 131 | 77.5 |
| | Extracurricular | 38 | 22.5 |

**Note: n* is below 169 due to missing data.

### 5.2. Descriptive Statistics

Table 2 shows the mean and standard deviations of the variables. The individuals' average ratings of team performance outcomes - group potency, team viability, and team cohesion - were relatively high on the 1 to 4 scale, with values of 3.22 (*SD* = .58), 3.05 (*SD* = .76), and 3.19 (*SD* = .66), respectively. The mean of individual-level compliance was 2.45 (*SD* = .75), indicating moderate compliance among individuals. The team-level average compliance was 2.35 (*SD* = .59), suggesting a slightly lower overall perception of compliance within teams. Significant differences were found between classroom and extracurricular project teams in team viability and individual-level compliance. While extracurricular project teams generally exhibited higher team viability, classroom teams demonstrated higher individual perception of compliance.

**Table 2: Means and Standard Deviations of Independent and Dependent Variables by Team Type**

| **Variables** | ***Classroom Project Teams*** | | ***Extracurricular Project Teams*** | | ***Whole Sample*** | |
|---|---|---|---|---|---|---|
| | Mean | *SD* | Mean | *SD* | Mean | *SD* |
| Individual Level | $N = 131$ | | $N = 38$ | | $N = 169$ | |
| Group potency | 3.19 | .57 | 3.32 | .59 | 3.22 | .58 |
| Team viability* | 2.97 | .77 | 3.32 | .65 | 3.05 | .76 |
| Team cohesion | 3.15 | .67 | 3.33 | .59 | 3.19 | .66 |
| Compliance* | 2.54 | .75 | 2.14 | .65 | 2.45 | .75 |
| Team Level | $N = 40$ | | $N = 12$ | | $N = 52$ | |
| Average compliance | 2.42 | .62 | 2.13 | .44 | 2.35 | .59 |

**Note:* statistically significant differences were observed between team types ($p < .05$).

## 5.3. Multilevel Results

### 5.3.1 The Unconditional Models (No Predictors): Variance Within and Between Groups

We calculated the intraclass correlation coefficient (ICC) (Raudenbush, 2002) based on the unconditional M0 models to examine the initial variations in team performance outcomes. The ICC, typically from 0 to 1, represents the proportion of total variance in the outcome that can be attributed to between-team differences versus within-team differences. In this study, 8% of the variance in group potency was due to differences between teams. In comparison, team-level differences accounted for 15% of the variance in both team viability and team cohesion. These ICCs fall within common ranges and suggest attention to modeling at the group as well as the individual levels (Westine et al., 2013).

### 5.3.2 Individual Compliance Effects

To answer the first research question, M1 models examined how compliance at the individual level predicted team performance outcomes (see Table 3).

Significant positive effects of individual perception of compliance were observed on all three outcomes: group potency ($\gamma_{10} = .198$, *SE* = .072, $p < .01$) team viability ($\gamma_{10} = .321$, *SE* = .082, $p < .001$), and team cohesion ($\gamma_{10} = .281$, *SE* = .072, $p < .001$). Team members who perceived higher levels of compliance tended to view their teams as more potent, viable, and cohesive. This finding highlighted the crucial role of individual perceptions in shaping team dynamics.

### 5.3.3 Individual vs. Team Compliance Effects

To answer the second research question, the M2 models expanded on the M1 analysis by separating the effects of compliance at two levels: individual perception relative to their team (Level 1) versus the team's average compliance (Level 2). This approach allowed us to determine whether team performance outcomes were driven more by individual-level compliance perceptions or by the team's overall compliance level.

The results, detailed in Table 3, showed that the positive effects of compliance remained significant at the **individual level (Level 1):** .223 (*SE* = .086, $p < .05$) for group potency, .364 (*SE* = .106, $p < .01$) for team viability, and .334 (*SE* = .076, $p < .001$) for team cohesion. Individuals who perceived higher levels of compliance relative to their teams were more likely to see their teams as more potent, viable, and cohesive.

At **the team level (Level 2)**, there was a significant positive relationship between average perceived compliance and group potency ($\gamma_{01} = .227,\ SE = .087, p < .05$) and team viability ($\gamma_{01} = .275, SE = .119,\ p < .05$). Teams with higher average levels of perceived compliance reported greater potency and team viability. However, no significant relationship was found between average compliance and team cohesion ($\gamma_{01} = .206,\ SE = .123, p > .05$), suggesting that team cohesion may be more strongly influenced by individual perception rather than the overall team compliance climate.

**Table 3: Fixed effects (Regression Coefficients) of the Multilevel Models**

| | **Group Potency** | | **Team Viability** | | **Team Cohesion** | |
|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M1** | **M2** | **M1** | **M2** |
| ***Level 1: Individuals*** | | | | | | |
| *Intercept,* $\gamma_{00}$ | 3.202*** (.045) | 3.071*** (.072) | 3.015*** (.068) | 2.866*** (.098) | 3.168*** (.057) | 3.045*** (.086) |
| *Compliance Slope,* $\gamma_{10}$ | .198* (.072) | .223* (.086) | .321*** (.082) | .364** (.106) | .281*** (.072) | .334*** (.089) |
| ***Level 2: Teams*** | | | | | | |
| *Average Compliance,* $\gamma_{01}$ | | .227* (.087) | | .275* (.119) | | .206† (.105) |

*Note:* ****p* < .001, ***p* < .01, **p* < .05, †*p* < .10; inside the parentheses are standard errors.

## 5.4. Exploratory Analysis and Results

### 5.4.1 Relationship Between Team Performance and Compliance Effects

To interpret our multilevel models in terms of the experiences of individuals within teams, we generated a unique scatterplot relating compliance to performance for each team. Each figure represented a different outcome, with compliance on the x-axis and the corresponding team performance measured on the y-axis. In these plots, each dot represented an individual, while the lines represented teams. Compliance was group-mean centered to illustrate how everyone's compliance score differed from the average compliance of their team (indicated by the red vertical dashed line at compliance = 0). For example, a compliance score of -1.0 indicated that the individual's score was 1 point below their team's average.

For group potency (Figure 1), the relationship between intercepts and slopes varied across teams, reflecting distinct relationships between individual compliance deviations (relative to team averages) and group potency within each team. Teams such as CF (yellow line) and CC (blue line) had relatively large intercepts but steep negative slopes. A high intercept indicated a high baseline group potency when individual compliance was at the team average. In contrast, the steep negative slopes suggested that as individual compliance increased beyond the team-perceived norm, group potency decreased. This pattern implied that greater deviations in individual compliance were associated with lower group potency in teams with high potency, potentially reflecting a misalignment between individual compliance and the team's overall sense of effectiveness.

In contrast, teams with low intercepts, such as team FR (purple line), showed steep positive slopes. The trend was that in teams where individual compliance deviations were positively correlated with group potency, the average group potency for those teams was lower. Moreover, several teams exhibited relatively flat lines, indicating a weak or nonexistent association between compliance deviation and group potency. In these teams, regardless of how much an individual's compliance deviated from the team's average perception of charter use, it had little effect on group potency. A similar pattern emerged in team viability and cohesion, with comparable intercept-slope relationships (Appendix 2).

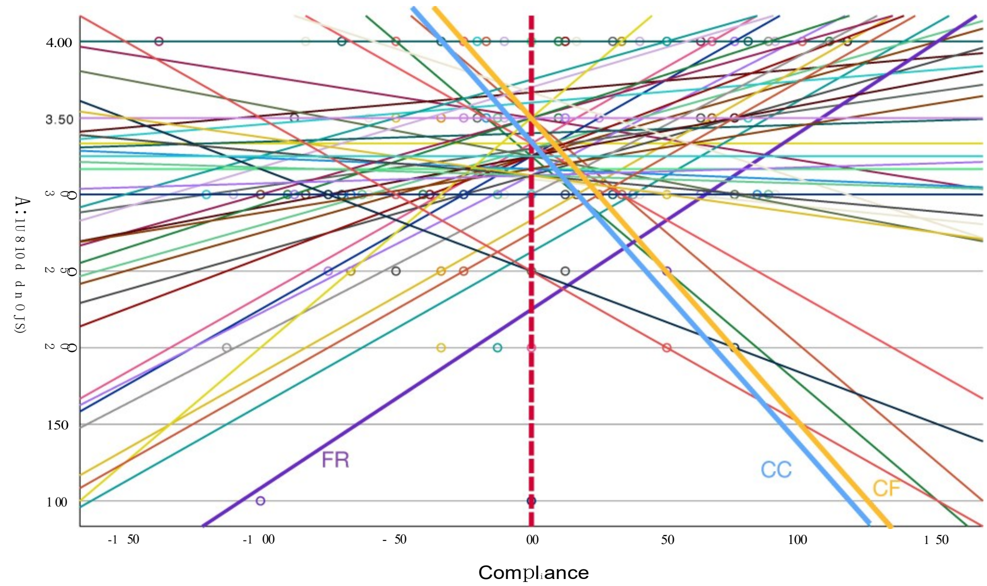


Fig 1. Relationship between Group Potency and Compliance Effects

Based on scatterplots, we proposed the following exploratory research questions (ERQs) for further study:

ERQl: How does a team's overall performance relate to the association between charter use compliance and team performance (i.e., group potency, team viability, and team cohesion) among members of the team?

ERQ2: Does a team perform better overall when those who are more compliantin charter use also perceive better performance?

As an initial response, we note the models revealed a strong negative correlation atthe team level between the intercept (/3。j) and the compliance slope (/31j) :-.872 for group potency, -.992 for team viability, and -.995 for team cohesion. These correlations suggested an inverse relationship: the larger the compliance effect, the lower the interceptfor each team performance outcome. In other words, teams with a strong positive correlation between compliance and a specific team performance outcome (i.e., group potency, team viability, or team cohesion) tend to have a lower average in that respective performance outcome.

### 5.4.2 Classroom vs. Extracurricular Project Team Effects

From the scatter plot analysis, we identified teams CC, CF, and FR, which exhibited contrasting trends. Upon close examination, we found that CC and CF were extracurricular project teams, while FR was a classroom team. These potential differences between classroom and extracurricular project teams led us to hypothesize that these teams may vary in their compliance patterns. To explore this, we introduced the team variable (classroom teams = 1 and extracurricular project teams = 0) at Level 2, extending the M2 models to M3 to assess the team effects on both the intercept and slope[2].

**Table 4: Fixed Effects (Regression Coefficients) of the Team Effects in M3**

| | Group Potency | Team Viability | Team Cohesion |
|---|---|---|---|
| ***Level 1: Individuals*** | | | |
| *(Intercept)*, $\gamma_{00}$ | $3.372^{***}$ | $3.380^{***}$ | $3.378^{***}$ |
| | (.101) | (.131) | (.120) |
| *Compliance Slope*, $\gamma_{10}$ | $.223^{*}$ | $.367^{**}$ | $.329^{***}$ |
| | (.087) | (.106) | (.087) |
| ***Level 2: Teams*** | | | |
| *Average Compliance*, $\gamma_{01}$ | $.277^{**}$ | $.368^{**}$ | $.266^{*}$ |
| | (.089) | (.116) | (.106) |
| *Team*, $\gamma_{02}$ | $-.241^{*}$ | $-.485^{**}$ | $-.295^{*}$ |
| | (.117) | (.152) | (.139) |

*Note:* $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$; inside the parentheses are standard errors.

As shown in Table 4, the results from the M3 models indicated that classroom teams had lower baseline scores compared to extracurricular project teams, as indicated by the negative coefficients

[2] The team variable on the compliance slope was tested but removed due to non-significance.

for the team variable: group potency ($\gamma_{02} = -.241$, $SE = .117$, $p < .05$), team viability ($\gamma_{02} = -.485$, $SE = .152$, $p < .01$), and team cohesion ($\gamma_{02} = -.295$, $SE = .139$, $p < .05$). That is, classroom teams scored, on average, .241 points lower on group potency, .485 points lower on team viability, and .295 points lower on team cohesion than extracurricular project teams. The compliance effects remained positive and significant at both the individual and team levels in the M3 models, consistent with the trends observed in the M2 models.

## 6. Discussion

The present study addresses the knowledge gap relating to the impact of consistent use of project charters on team performance within engineering project-based education. While previous research has demonstrated the benefits of implementing project charters, this study extends these findings by focusing on perceived compliance rather than simply having a charter in place (Aaron et al., 2014). Our findings reveal that consistent use of project charters in PBL in engineering education and workforce development settings, as measured by perceived compliance, was crucial for team performance, improving group potency, team viability, and team cohesion. This focus on perceived compliance aligns with research emphasizing the importance of perceived psychological contracts in teams, highlighting the importance of unwritten expectations and obligations in shaping team dynamics (Johnson et al., 2022b). However, integrating charters into PBL to effectively guide interactions and develop collaboration skills in engineering settings remains a challenge (Dougherty et al., 2018) due to multi-level (i.e., individual and team levels) and multi-faceted (i.e., individual, dyad, and team dynamics such as demographics, prior experience, and team chemistry) nature of teams, difficulty in optimizing level of exposure to and structured use of project charters in the classroom and larger organizational environment settings, and work context.

Our study examined perceived compliance with charter use at both individual and team levels, using MLM to differentiate their effects. The findings indicate that personal beliefs and collective team perceptions of charter use both contribute significantly and almost equally to team performance, including group potency, team viability, and cohesion. As an initial exploration of the follow-up exploratory research questions, two main patterns emerged that clarified how a team's overall performance (i.e., group potency, team viability, and team cohesion) influenced the relationship between compliance and performance among members of the team (Leicht et al., 2009). The relationship between individual charter use and individual performance varied across teams depending on the performance of the teams. This suggests that team dynamics may shape the relationship between compliance and team performance. Specifically, the link between individual compliance and performance in high-performing teams tended to be weaker. In these teams, individuals who perceived themselves as more compliant in charter use than other team members did not necessarily report better-perceived team performance. This finding suggests that individuals' compliance with charter use alone in high-performance teams may not be the key driver of individuals' perceived positive team outcomes such as group potency, team viability, and team cohesion (Mathieu & Rapp, 2009). Instead, factors such as team communication composition, communication patterns, leadership style, or the team's flexibility in responding to challenges play a larger role (Cox & Bobrowski, 2000). While compliance with charter use supports team structure and order, it does not consistently improve individual performance. Future research could investigate how these broader aspects of team context moderate the compliance-performance relationship and under what conditions compliance enhances performance.

This study also demonstrated the impact of setting - classroom versus extracurricular – on engineering project-based learning. Classroom teams typically begin with lower levels of group potency, team viability, and cohesion compared to teams in extracurricular project teams. This discrepancy can be attributed to the distinct environments in which these teams operate. In classroom settings, students often collaborate in their teams for the first time under rigid deadlines, which limits opportunities for organic team development (Courtney et al., 2007). The short-term nature of classroom projects restricts the time available to build effective working relationships and shared goals, often resulting in a lack of shared mental models (Carraro et al., 2024) and lower initial team performance. In contrast, extracurricular project teams (e.g., competition teams in student clubs, center teams for training and innovation implementation) consist of members who have prior experience working together and may participate in repeat projects. This familiarity fosters a more flexible environment, accelerating team dynamics development (Edmondson & Nembhard, 2009). With trust and alignment already established, extracurricular project teams generally achieve higher performance levels from the beginning and require less training on team formation and management that project charters can reinforce. However, the repetitive nature of extracurricular project projects can lead to compliance fatigue, where individuals familiar with the charters may become disengaged. These findings suggest that workforce development strategies for engineering teams should be tailored to account for these distinctions. While classroom teams seem to benefit from structured guidance to enhance team dynamics, which can be achieved through training with, exposure to, and ways to integrate project charters within assignment execution (e.g., time allocated in the classroom for teams to co-create and maintain project charters, points allocated in assignment rubrics to motivate collaborative use of charters); extracurricular project teams may require strategies to maintain focus, motivation, and coordination over time (e.g., use of a Ganttbot [Pereira & Díaz, 2021] for automated reminders of key milestones, recognition programs and incentives for success).

## 7. Conclusion

This study explored the impact of perceived compliance with project charter use at both the individual and team levels on key team performance outcomes (i.e., group potency, team viability, and cohesion) for engineering student project teams in both classroom and extracurricular project team settings. By employing a multilevel modeling approach, the present study differentiated the effects of individual perceptions from those of the collective team perceptions on these team performance outcomes.

The findings revealed that consistent use of project charters, assessed through perceived compliance, is linked to significant improvements in team performance, especially in classroom project settings. Furthermore, in high-performing teams, individuals who perceived themselves as more compliant in charter use than other team members did not necessarily report better individual performance. This finding suggests that in high-performance teams, compliance alone may not be the key driver of positive team outcomes. Future research could investigate how these broader aspects of team context moderate the compliance-performance relationship and under what conditions compliance enhances performance.

When interpreting the differences between classroom and extracurricular project teams, it is important to consider the potential effects of sample size. In the present study, classroom teams included 131 members across 40 teams, while extracurricular project teams had 38 members across 12 teams. Therefore, we recommend that future studies delve deeper into studying effective ways of implementing charter use for PBL in various engineering education and workforce development settings considering work context, modality of education (e.g., classroom versus extracurricular, for pay versus for grade or experience), team composition (e.g., level of education, experience, and skill heterogeneity), project nature, and prior relationships among team members.

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