Measuring the Effects of Structured Roles in Digital Collaborative Learning (NSF Award #2121412 - Enhancing Equity and Access Via Digitally-mediated Collaborative Learning Experiences)

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1 Motivation

Collaborative learning has been shown to improve student outcomes in computing education, including increased sense of belonging, learning gains, and self-efficacy [1, 2, 3]. To support productive collaboration, researchers have investigated structured role assignments that promote individual accountability, positive interdependence, and equitable participation [4]. Evidence from collaborative learning environments suggests that role structures can improve performance [5], reduce completion time, and increase equality in student contributions [1]. These structured approaches have been adopted to model cognitive process and ensure all group members contribute meaningfully [4].

Existing research has primarily examined role structures that are maintained throughout entire collaborations, leaving open the question of whether formal role enforcement remains necessary after groups establish working relationships and norms. Recent works suggests that some collaborative structures matter more than others: while team consistency significantly impacts learning outcomes and sense of belonging, other structural constraints such as meeting times show no significant effects [6]. This raises the possibility that once collaborative norms are established, rigid enforcement of roles structures may be unnecessary and potentially counterproductive if it constrains natural group processes. This study addresses this gap by examining what happens when structured roles are removed mid-semester after groups have had time to establish norms. We investigate two complementary research questions:

RQ 1: How do students' collaborative experiences shift when roles are removed mid-semester after group norms have been established (within-person changes)?

RQ 2: Do students in role-enforced groups report different experiences than similar peers whose groups operate without role constraints (between-group differences)?

2 Methods

This study was conducted under IRB approval in the course *Numerical Methods* at the University of Illinois Urbana-Champaign, taken generally by second- through fourth-year computer science, math, and other related field majors. The course featured weekly in-person group activities (GAs), where students collaborated in groups of 2-3 members to complete an assignment comprised of up to two extended coding questions and free-response problems. Students had the

option to complete GAs alone for diminished credit. All the GAs were completed via an online platform that supports autograded assessments [7].

2.1 Post-GA Survey

At the end of the group activity, students were asked to complete a survey reflecting on their group's collaboration that day. Survey questions 1 and 2 asked about assignment difficulty and support resources used, but these measures are not analyzed in this study. Survey questions 3–6 measured sense of belonging; these items, shown in Table 1, are the focus of the present analysis.

ID	Topic	Question & Response Options
Q3	Inclusion	My group made an effort to include me in discussions. *(True/False/Alone)*
Q4	Social talk	We talked about our lives outside of class. *(True/False/Alone)*
Q5	Cohesion	My group worked well together. *(True/False/Alone)*
Q6	Future	I am looking forward to seeing my group again. *(True/False/Alone)*

Table 1: Relevant post-GA survey questions measuring sense of belonging.

2.2 Roles

There were three roles defined within a GA: manager, recorder, and reflector. The *manager* was in charge of facilitating discussion among group members and making sure all members had the opportunity to contribute. The *recorder*'s responsibility was to document code and submit it to the autograder. Finally, the *reflector*'s role was to ensure all members were caught up on what was going on and understand the discussion; the reflector would also submit the post-GA survey (Section 2.1). After a student joined a GA, they selected a role from the available options. Once selected, they were inherently limited to the scope of their role in terms of ability to interact within the assignment. The recorder had the ability to submit code; the reflector had access to the post-GA survey and the manager was the only one able to change the role assignments. The course instructor encouraged students to alternate roles across the semester.

2.3 Experimental Design

We employed a quasi-experimental design to examine how structured role assignments influence students' collaborative experiences. At the beginning of the semester, students completed a pre-course survey measuring baseline sense of belonging on a 5-point Likert scale. Items mirrored the post-GA belonging questions (Table 1, Q3-Q6). These baseline scores were used as control variables in our analyses. All students began the semester working in groups with roles enabled, allowing groups to establish norms and familiarity over the first seven weeks. Starting with GA 8, we introduced a split condition: half of the groups (Cluster A, $n = 55$ students in 17 groups) continued working with roles enforced, while the other half (Cluster B, $n = 45$ students in 12 groups) had roles removed. This split persisted through GAs 8, 9, 10, and 12, with GA 11 serving as a universal "roles-off" week for all students, and GA 13 returning all groups to

roles-enabled. By maintaining consistent instructors, content, and scheduling across both clusters, we isolated the role structure as the primary varying factor.

2.4 Analysis

Within-Group Analysis. For Cluster B students, we used mixed-effects logistic regression to examine changes across all 13 GAs, controlling for students' pre-course belonging survey responses and isolating role effects from pre-existing differences. For sense-of-belonging outcomes (Questions 3-6), we used a similar mixed-effects model with student-level random effects. We fit the following general model separately for each question:

$$\text{Response}_{ij} = \beta_0 + \beta_1 \cdot \text{RoleStatus}_{i,j} + \beta_2 \cdot \text{PreSurvey}_i + u_i + \varepsilon_{ij} \quad (1)$$

where Response_{ij} is the response (coded as 1 for 'True' or 0 for 'False') included in the j^{th} GA by student i, $\text{RoleStatus}_{i,j}$ indicates whether roles were enabled (1) or not (0), PreSurvey_i controls for students' baseline belonging scores, u_i represents student-level random effects, and ε_{ij} is residual error.

To examine whether role structure affected students' engagement patterns, we also analyzed submission timing within Cluster B. We hypothesized that students without assigned roles might exhibit less coordinated engagement, with submissions distributed more variably throughout the assignment period. For each student submission event on the GA due date, we calculated elapsed time in hours since the GAs open. Submission timing data showed substantial right skew, making the non-parametric Mann-Whitney U test appropriate to compare median elapsed hours between roles-on GAs (1, 2, 3, 4, 5, 6, 7, 13) and roles-off GAs (8, 9, 10, 11, 12) for Cluster B students.

Between-Group Analysis. To compare Clusters A and B during the split period (GAs 8, 9, 10, 12), we employed independent samples t-tests for sense-of-belonging measures. We also compared submission timing patterns between clusters using Mann-Whitney U tests, following the same methodology described above for the within-group analysis.

3 Results

3.1 Within-Group Analysis

We examined whether role enforcement affected Cluster B students' sense-of-belonging responses across all 13 GAs. Figure 1 shows the proportion of students responding "True" to each sense-of-belonging question throughout the semester. While inclusion (Q3), cohesion (Q5), and future belonging (Q6) remained consistently high regardless of role status, social talk (Q4) showed an increase after roles were removed.

To quantify these patterns, we used mixed-effects logistic regression with student-level random effects. We fit the model described in Equation 1 separately for each of the four sense-of-belonging questions. Models were controlled for students' pre-course belonging scores (1-5 Likert scale). Results are shown in Table 2.

Role enforcement significantly reduced social talk outside of class activities (Q4: $\beta = -0.65$, $p < 0.001$), suggesting that structured roles focused groups more narrowly on task completion.

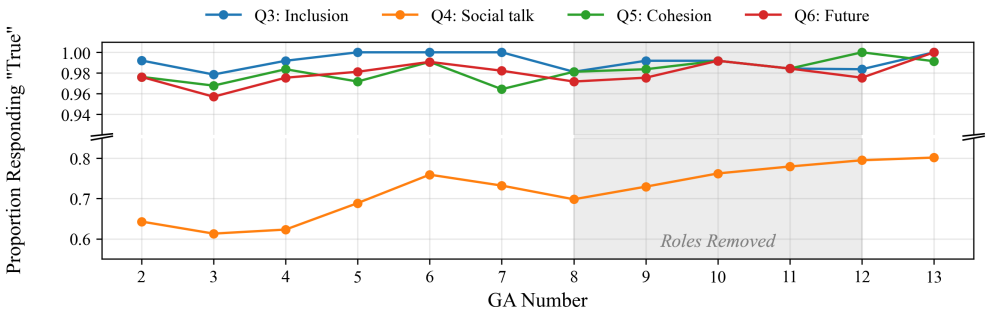

Figure 1: Proportion of Cluster B students responding "True" to sense-of-belonging questions across all GAs. The y-axis is broken to show variation in Q4 alongside the consistently high Q3, Q5, and Q6 responses.

Question	β_{Role}	p_{Role}	β_{Pre}	p_{Pre}	**Mean On**	**Mean Off**
Q3: Inclusion	1.21	0.120	0.59	0.343	0.99	0.99
Q4: Social talk	-0.65	<0.001*	1.51	<0.001*	0.74	0.75
Q5: Cohesion	-0.59	0.223	0.17	0.571	0.98	0.99
Q6: Future	-0.14	0.801	0.97	0.155	0.99	0.98

Table 2: Mixed-effects logistic regression results for sense-of-belonging questions.

Pre-course belonging scores strongly predicted social talk ($\beta = 1.51$, $p < 0.001$), indicating students with higher baseline belonging engaged more socially. No other sense-of-belonging measures showed significant effects of role enforcement.

Submission timing differed significantly by role status ($U = 11{,}327{,}540.5$, $p < 0.001$). When roles were enforced, students submitted later on average (mean $M = 131$ minutes after the GA opened, median $Mdn = 81$ minutes, standard deviation $SD = 132$) compared to when roles were removed ($M = 109$ minutes, $Mdn = 73$ minutes, $SD = 110$).

As an exploratory analysis, we examined whether role effects differed by gender identity by adding gender minority status (women/non-binary vs. men), role status, and their interaction to our within-group models for Cluster B. The interaction term tests whether the effect of role enforcement on sense of belonging differed between gender minority and majority students. No significant interactions emerged (Q3: $\beta_{interaction} = 0.003$, $p = 0.743$; Q4: $\beta_{interaction} = -0.003$, $p = 0.934$; Q5: $\beta_{interaction} = 0.157$, $p = 0.300$; Q6: $\beta_{interaction} = 0.012$, $p = 0.375$), indicating that role removal affected gender minority and majority students similarly for sense-of-belonging measures.

3.2 Between-Group Analysis

None of the sense-of-belonging measures differed significantly between clusters during the split period (Table 3a), suggesting that enforcing roles in Cluster A versus removing them in Cluster B did not differentially affect students' reported group experiences.

Submission timing patterns varied across GAs, with one significant difference emerging in GA 12

Question	t-stat	p-value
Q3: Inclusion	0.659	0.510
Q4: Social talk	-0.007	0.994
Q5: Cohesion	0.076	0.940
Q6: Future	-1.00	0.319

(a) Sense-of-belonging measures (independent samples t-tests)

GA	Cluster	Mean	Mdn	p
8	A	1.95	1.33	0.052
	B	2.19	1.37	
9	A	1.72	1.10	0.652
	B	1.33	1.10	
10	A	1.88	1.28	0.362
	B	1.98	1.21	
12	A	2.56	1.34	0.002*
	B	2.05	1.26	

(b) Submission timing in hours (Mann-Whitney U tests)

Table 3: Between-group comparisons during split GAs (8, 9, 10, 12). No significant differences were found for sense-of-belonging measures (a). Cluster A submitted significantly later than Cluster B only in GA 12 (b).

(Table 3b). In GA 12, Cluster A (roles enforced) submitted significantly later ($M = 154$ minutes, $Mdn = 80$ minutes) than Cluster B (roles removed; $M = 123$ minutes, $Mdn = 76$ minutes), $U = 492{,}605$, $p = 0.002$. GAs 8, 9, and 10 showed no significant timing differences.

Exploratory analysis examined whether submission timing differences between clusters varied by gender identity. A significant interaction emerged ($\beta_{interaction} = -0.286$, $p < 0.001$), with gender majority students in Cluster B submitted approximately 16 minutes later than those in Cluster A ($\beta_{cluster} = 0.271$, $p < 0.001$), while gender minority students submitted earlier overall across both clusters ($\beta_{gender} = -0.064$, $p < 0.001$). Despite these statistical differences, the modest effect sizes and lack of consistent patterns across individual GAs suggest no systematic participation disadvantage for either gender group once norms were established.

4 Discussion

Our findings reveal that once collaborative norms are established, formal role structures have limited influence on students' sense of belonging or participation patterns. The modest effect sizes suggest that group-level norms may be more influential than structural interventions once groups have formed working relationships. These results highlight the importance of timing when implementing collaborative structures, as rigid enforcement of roles throughout extended collaborations may be unnecessary and potentially counterproductive if it constrains natural group processes without yielding meaningful benefits. These findings suggest that uniform collaborative structures may not account for how established groups adapt and self-organize. Future work should examine how role structures affect groups at different developmental stages.

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