

The Structural Interaction between Teachers' Collaboration and Inquiry-Based Learning Networks: Effects on the Implementation of Inquiry-Based Learning

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Abstract — The purpose of this study is to clarify the structural relationship between teacher collaboration and Inquiry-Based Learning (IBL) networks in the diffusion process of IBL among Japanese teachers ($N = 650$). Teacher collaboration was measured using three subscales: teacher collaboration among colleagues (CF1), leadership by administrators (CF2), and partnerships with communities and parents (CF3). The analysis revealed high correlations among CF1–CF3 ($r = .62-.69$) and moderate correlations with the IBL Network ($r = .31-.41$), indicating the interconnection between intra-school and extra-school collaborative cultures and IBL networks. Furthermore, a Seemingly Unrelated Regression (SUR) model demonstrated a statistically significant reciprocal facilitation relationship between collaboration and the IBL network. These results suggest that the diffusion of IBL is mutually promoted by strong internal interactions (collaboration within schools), external network linkages (diffusion across contexts), and the formation of inquiry-related teacher networks.

Keywords – teacher network, inquiry-based learning, teacher collaboration, creativity, creative problem-solving

I. INTRODUCTION

A. The Purpose of This Study

The purpose of this study is to investigate how teacher collaboration and teacher networks in Inquiry-Based Learning (IBL) influence the implementation of IBL practices. Specifically, this study explores how IBL can be sustainably integrated with existing subject-based education and school culture, rather than remaining as “inquiry for the sake of inquiry.” Moreover, it examines the hypothesis that teacher collaboration not only facilitates the formation of IBL networks but that participation in inquiry-related activities, in turn, stimulates intra-school collaboration—thus forming a reciprocal facilitation relationship between the two.

B. Research Background

In recent years, Inquiry-Based Learning (IBL) has gained international attention as a pedagogical approach that fosters learners' autonomy, creativity, and

problem-solving skills [1]. IBL promotes active, dialogic, and deep learning, and has been widely recognized as an effective means of cultivating 21st-century skills such as creative and critical thinking [2]. In Japan, revisions to the national curriculum have introduced the “Period for Inquiry-Based Learning,” emphasizing the need to enrich inquiry-oriented learning [3].

However, many teachers have never experienced IBL themselves during their own schooling, and consequently, they often develop teaching methods through a process of trial and error [4]. The diffusion and institutionalization of such new learning paradigms require not only individual effort but also cultural support at the whole-school level and collaboration among colleagues [5]. Recent research has repeatedly highlighted that teacher collaboration—including collegial partnerships, leadership by school administrators, and engagement with local communities—plays a crucial role in sustaining educational reform [6], [7].

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Furthermore, the introduction of IBL is closely related to the formation of networks that connect teachers with external communities for sharing information and teaching resources [8]. Inquiry-oriented practices evolve not only through intra-school collaboration but also through cooperation with actors outside of school, such as other institutions, communities, and experts [9]. Therefore, understanding the diffusion of inquiry-based learning requires attention to the mutual interconnection between school culture and external networks.

Nevertheless, how these networks are intertwined with existing educational practices and teacher cultures remains insufficiently understood. For IBL to be established not as a departure from conventional subjects (e.g., language arts, mathematics, science), but as a restructured mode of learning that integrates these disciplines, collaboration and networking in inquiry learning must be connected to the everyday collaborative culture among teachers [10]. From this perspective, the challenge lies not in conducting inquiry for inquiry's own sake but in bridging existing subject-based education with an emerging culture of inquiry.

C. Theoretical Background

A school culture that supports creativity and openness to innovative teaching practices serves as an essential foundation for teachers' engagement in inquiry-oriented practice [2]. When teachers regularly participate in joint curriculum design and reflective practices, a culture of inquiry is fostered within the school [6]. At the same time, external professional networks also contribute to promoting IBL [7]. By forming communities that transcend subject areas, schools, and regions, teachers facilitate both horizontal learning within schools and vertical diffusion beyond school boundaries. These studies suggest that the diffusion of an inquiry-oriented culture progresses through the interactive dynamics between internal collaboration (teacher collaboration) and external linkages, forming a dual-layered structural interaction.

D. Problem Identification and Research Questions

Previous research has demonstrated that teacher collaboration provides a vital foundation for educational reform [11]; however, how it interacts with the formation of IBL networks has not been sufficiently examined. In particular, little empirical evidence exists regarding whether intra-school collaborative culture (e.g., collegial support, leadership by administrators, and community partnerships) promotes the formation of IBL networks, and whether those networks, in turn, revitalize intra-school collaboration—forming a reciprocal facilitation relationship.

This study quantitatively models this bidirectional relationship and aims to clarify how the diffusion of inquiry-based culture develops through complex networks both inside and outside schools.

Accordingly, this study addresses the following research questions (RQs):

- RQ1: To what extent are teacher collaboration (teacher collaboration among colleagues, leadership, community partnership) and the Inquiry-Based Learning Network (IBL Network) interrelated?
- RQ2: Does a reciprocal facilitation relationship exist between teacher collaboration and inquiry-based learning networks?
- RQ3: Does teaching experience in IBL function as a mediating factor influencing both collaboration and network formation?

By addressing these questions, this study proposes a theoretical framework that conceptualizes the diffusion of IBL as a process of cultural evolution that connects existing school culture and subject-based instruction with emerging inquiry-oriented practices.

II. RESEARCH METHOD

A. Survey Method and Targets

In March 2025, we conducted a web-based questionnaire survey of 650 Japanese teachers. Screening ensured that respondents were full-time teachers employed at elementary, middle, or high schools. The survey was administered anonymously, and no personally identifiable information was collected. Prior to responding, participants were provided with an explanation of the survey and asked to provide consent; only those who consented proceeded to the questionnaire. Because no personal information was collected, responses could not be withdrawn after submission.

As shown in Table 1, the mean age of respondents was 50.8 years ($SD = 10.5$), and the mean number of working years was 26.3 ($SD = 11.6$). As indicated in Table 2, the gender ratio was 484 males (74.5%) and 166 females (25.5%). By school type, there were 216 elementary (33.2%), 217 middle (33.4%), and 217 high school teachers (33.4%). While the distribution by school type and gender was generally balanced, a higher proportion of males was observed among high school teachers.

Table 1. Descriptive Statistics of Age and Years of Teaching Experience

Item	Mean	SD
Age	50.81	10.47
Working year	26.33	11.57

($N = 650$)

Table 2. Distribution by Gender and School Type

	Elementary	Middle	High	Total
Male	124	166	194	484
Female	92	51	23	166
Total	216	217	217	650

B. Survey Items

The survey items used in this study are listed in Table 3. To measure teacher collaboration, we adopted the instrument developed by Yoshida and Yoshizawa [12],

[13]. In this paper, we used all original items rather than the shortened version. To capture teacher networks related to inquiry-based learning, we constructed the items shown in Table 4 based on author discussions. The IBL Network scale in this study assumes a multi-layered network that includes cross-disciplinary collaboration within schools, collaborative development of inquiry teaching materials, and linkages with external experts. The conceptualization was informed by Friesen [14] and the inquiry-based professional networks [8].

C. Analysis Procedure

We conducted the following four analytical steps:

- 1) Reliability analysis and descriptive statistics for each scale.
- 2) Correlation analysis among CF1–CF3, Overall Collaboration (composite teacher-collaboration scale), and the IBL Network.
- 3) Multiple regression analysis examining how School type, IBL experience, Gender, Age, and Working year affect CF1–CF3, Overall Collaboration, and the IBL Network.
- 4) Simultaneous estimation of the bidirectional relationship using a Seemingly Unrelated Regression (SUR) model.

First, for (1), we assessed the reliability of each scale using Cronbach's α and McDonald's ω . For (2), we examined correlations among CF1 (teacher collaboration among colleagues), CF2 (leadership by administrators), CF3 (school–community partnerships), Overall Collaboration (composite teacher-collaboration index), and the IBL Network, in order to understand the baseline relational structure among variables. This step clarifies the direction and strength of associations between the subcomponents of teacher collaboration and network formation, thereby informing subsequent model analyses.

For (3), we applied multiple regression analyses to investigate the effects of School type, IBL experience, Gender, Age, and Working year on teacher collaboration and the IBL Network. This allowed us to statistically confirm how teacher attributes and organizational factors influence collaboration and network formation, and to identify basic tendencies.

Finally, for (4), we employed a Seemingly Unrelated Regression (SUR) model to simultaneously estimate the bidirectional relationship between teacher collaboration and the IBL Network. SUR is a multivariate regression framework that jointly estimates multiple regression equations while accounting for the correlation structure among their error terms, thereby improving estimation efficiency [15]. It is applicable when each equation has different dependent and explanatory variables but may be affected by related external factors or common shocks; by leveraging information sharing

across equations, SUR can reduce the variance of coefficient estimates [16]. In other words, whereas conventional single-equation regression captures only unidirectional effects, SUR allows us to test a mutually facilitative structure between intra-school culture (teacher collaboration) and the formation of inquiry-related networks while taking into account correlated disturbances.

Through these analyses, we aim to capture, from multiple perspectives, the collaborative structures within and beyond schools that support the diffusion of IBL.

III. RESULTS

A. Descriptive Statistics and Group Differences

Table 5 presents the results of the reliability analysis for each scale. All Cronbach's α coefficients were $\geq .78$, and all McDonald's ω coefficients were $\geq .87$. Thus, each factor used in this study demonstrates sufficient internal consistency.

We then computed descriptive statistics. As shown in Table 6, the means differed by IBL experience. In particular, teachers with IBL experience scored significantly higher on CF1 (teacher collaboration among colleagues), CF3 (school–community partnerships), and Overall Collaboration ($t = 2.88$ – 4.02 , $p < .001$), with medium effect sizes (Cohen's d). No between-group difference was observed for CF2 (leadership by administrators). For the IBL Network, the experienced group also showed a significantly higher mean ($t = 8.94$, $p < .001$, $d = 0.71$), indicating that teachers who engage in IBL practice are more active in forming collaborative ties. In other words, teachers with IBL experience tend to have more opportunities—both inside and outside school—for information sharing, material development, and cross-subject collaboration related to inquiry, resulting in higher IBL Network scores.

B. Results of the Correlation Analysis

As shown in Table 7, the subscales of teacher collaboration (CF1–CF3) were highly and positively interrelated ($r = .62$ – $.69$, $p < .001$), confirming that collaborative activities within and beyond schools form an integrated structure. Correlations with the IBL Network were of moderate magnitude ($r = .31$ – $.41$, $p < .001$), suggesting a composite structure in which collaborative culture and IBL networks are interconnected across intra- and extra-school contexts.

Here, the composite index Overall Collaboration comprises three subdimensions: CF1 (teacher collaboration among colleagues), CF2 (leadership by administrators), and CF3 (school–community partnerships). Given the high intercorrelations among the subscales ($r = .62$ – $.69$, $p < .001$) and acceptable multicollinearity ($VIF \approx 2$ for all), we focus on the higher-order construct representing the school's collaborative culture.

Table 3. List of Key Variables Used in This Study

Category	Variable	Construct / Content	Scale / Notes
Dependent variables	CF1 (Teacher collaboration among colleagues)	Degree of teacher collaboration among colleagues, information sharing, and mutual help among teachers	5-point Likert (1 = strongly disagree ~ 5 = strongly agree) [12], [13] (same as above)
	CF2 (Leadership by administrators)	Support from principals/vice-principals, direction-setting, fair operation	(same as above)
	CF3 (school–community partnerships)	Extent of collaboration and exchange with communities and parents	(same as above)
	IBL Network (Teacher network for IBL)	Intra-/extra-school networks related to IBL	5-point Likert (1 = does not apply at all ~ 5 = applies very well)
Independent variables	IBL experience	Whether the respondent has taught IBL	Binary (0 = no, 1 = yes)
	School type	Type of school to which the teacher belongs	Nominal (1 = elementary, 2 = middle, 3 = high)
Control variables	Gender	Respondent's gender	Nominal (1 = male, 2 = female)
	Age	Teacher's age (real value)	Open response
	Working year	Years of teaching experience (real value)	Open response

Table 4. Items Measuring Teacher Networks for Inquiry-Based Learning (IBL)

1	I regularly share information with colleagues regarding the planning of IBL and the study of teaching materials.
2	I have opportunities to collaborate with teachers of other subjects to jointly design and implement cross-disciplinary inquiry tasks.
3	Within the school, there are well-established venues (e.g., study groups, workshops) for exchanging know-how and case examples related to IBL.
4	When instructional issues arise in implementing IBL, there is a climate where I can readily consult with colleagues.
5	I participate in extra-school networks or communities (e.g., other schools or local organizations) related to IBL.
6	Even when I am in charge of IBL, I often feel isolated due to having few colleagues in school with whom I can consult.*
7	Networks among IBL practitioners are insufficient, making information exchange and collaborative research difficult.*

* Reverse-coded item

Table 5. Reliability Coefficients for Each Scale/Factor (Cronbach's α and McDonald's ω)

Factor	Number of Items	Cronbach's α	McDonald's ω
CF1	9	0.919	0.941
CF2	8	0.955	0.966
CF3	12	0.937	0.946
Overall Collaboration	29	0.963	0.973
IBL Network	7	0.786	0.879

Note. CF1 = teacher collaboration among colleagues; CF2 = leadership by administrators; CF3 = school–community partnerships; Overall Collaboration = composite teacher-collaboration scale; IBL Network = teacher network for inquiry-based learning.

Table 6. Descriptive Statistics Overall and by IBL Implementation (IBL Experience)

Variable	All ($N = 650$)		Experienced ($N = 365$)		Inexperienced ($N = 285$)		t	d
	Mean	SD	Mean	SD	Mean	SD		
CF1	3.324	1.079	3.360	1.085	3.278	1.070	2.882***	0.228
CF2	3.236	1.156	3.239	1.181	3.233	1.124	0.181	0.014
CF3	3.244	1.035	3.283	1.055	3.194	1.006	3.773***	0.298
Overall Collaboration	3.267	1.084	3.295	1.101	3.231	1.060	4.018***	0.318
IBL Network	2.749	0.716	2.877	1.113	2.584	1.085	8.941***	0.707

*** $p < .001$

Note: CF1 = teacher collaboration among colleagues; CF2 = leadership by administrators; CF3 = school–community partnerships; Overall Collaboration = composite teacher-collaboration scale; IBL Network = teacher network for inquiry-based learning.

Table 7. Correlation Coefficients among Teacher Collaboration Variables and the IBL Network

	CF1	CF2	CF3	Overall Collaboration	IBL Network
CF1	1.000	0.689***	0.648***	0.872***	0.373***
CF2		1.000	0.623***	0.872***	0.312***
CF3			1.000	0.883***	0.413***
Overall Collaboration				1.000	0.421***
IBL Network					1.000

*** $p < .001$

($N = 650$)

Note. CF1 = teacher collaboration among colleagues; CF2 = leadership by administrators; CF3 = school–community partnerships; Overall Collaboration = composite teacher-collaboration scale.

In the regression analyses, CF1, CF2, CF3, Overall Collaboration, and the IBL Network were used as dependent variables; in the subsequent SUR analysis, we used Overall Collaboration and the IBL Network.

C. Multiple Regression Analysis

Before estimation, we tested interaction effects between School type and IBL experience for all dependent variables; none were significant in any model. We therefore report main-effect models.

Table 8 summarizes the multiple regression results with CF1–CF3, Overall Collaboration, and the IBL Network as dependent variables. Elementary school served as the reference category for School type, with middle school (SC2: Middle–Elementary) and high school (SC3: High–Elementary) included as dummies.

Across all collaboration-related outcomes, high school teachers (SC3) scored significantly lower than elementary teachers (CF1: $b = -0.434$, $p < .001$; CF2: $b = -0.524$, $p < .001$; CF3: $b = -0.435$, $p < .001$; Overall Collaboration: $b = -0.459$, $p < .001$). Middle school status (SC2) was not significant ($p > .05$ for all). IBL experience showed a significant positive effect on CF3 ($b = 0.134$, $p < .05$), a trend-level effect on CF1 and overall collaboration ($p < .10$), and a nonsignificant effect on CF2. Gender, Age, and Working Year were not significant predictors of any collaboration outcome. For overall collaboration, $R^2 = .076$, suggesting that attributes alone explain 7.6% of the variance, and that additional organizational or individual factors likely contribute.

For the IBL network model, only IBL experience showed a significant positive effect ($b = 0.311$, $p < .001$). School type, Gender, Age, and Working Year were nonsignificant. The model R^2 was .061, indicating that IBL practice experience is the primary explanatory factor for variance in the IBL Network.

D. Seemingly Unrelated Regression (SUR)

As shown in Table 9, we employed a Seemingly Unrelated Regression (SUR) framework to simultaneously estimate the collaboration equation and the IBL network equation.

In the model with overall collaboration as the dependent variable, the effect of the IBL network was significantly positive ($b = 0.748$, $p < .001$), indicating that teachers more active in networked activities tend to report stronger intra-school collaborative culture. High school status (vs. elementary) was significantly negative ($b = -0.382$, $p < .001$), suggesting comparatively stronger collaborative culture in elementary and middle schools. IBL experience showed a small negative coefficient ($b = -0.137$, $p < .05$), implying a possible indirect pathway via network formation. Working Year showed a positive trend ($b = 0.007$, $p < .10$), consistent with the idea that accumulated

experience contributes to deepening collaborative culture. The model showed moderate explanatory power ($R^2 = .164$).

In the model with the IBL network as the dependent variable, the effect of overall collaboration was significantly positive ($b = 0.698$, $p < .001$), indicating that stronger intra-school collaboration is associated with greater participation in inquiry-related networks. High school teachers scored higher than elementary teachers ($b = 0.218$, $p < .001$), and IBL experience also had a significant positive effect ($b = 0.244$, $p < .001$). Working Year showed a negative effect ($b = -0.008$, $p < .05$), suggesting more active network formation among relatively younger teachers. Age and gender were nonsignificant. The model exhibited good overall fit ($R^2 = .151$). The residual correlation between the two equations was high ($r = -.879$), indicating strong coupling between the two structures.

For the pathway, IBL experience \rightarrow IBL network \rightarrow overall collaboration, the indirect effect was $a \times b = 0.244 \times 0.748 = 0.1825$, whereas the direct effect from IBL experience to overall collaboration was -0.137 , suggesting the relative importance of the mediated pathway. In summary, these relationships are organized as shown in Figure 1.

IV. DISCUSSION

This study examined the structural relationship between teacher collaboration and inquiry-based learning networks (IBL Network) among 650 teachers working in Japanese elementary, middle, and high schools. Using multiple regression alongside a Seemingly Unrelated Regression (SUR) framework, we found a statistically significant reciprocal facilitation relationship between the two constructs. In this section, we discuss the findings in light of the literature and the study context.

A. Overlap and Functional Differentiation between Teacher Collaboration and the IBL Network

The IBL Network scale employed in this study captures a hybrid structure of collaborative elements spanning both intra- and extra-school contexts, such as information sharing on the planning of IBL and the study of teaching materials, collaboration with teachers across subjects, internal study groups and consultation opportunities, and participation in external IBL networks across communities and schools. Accordingly, the IBL Network in this study is not a network independent of existing collaboration, but one that strengthens intra- and extra-school collaboration mediated by inquiry practices.

Correlation analysis showed that the three subfactors of teacher collaboration—CF1 (Teacher collaboration among colleagues), CF2 (leadership by administrators), and CF3 (school–community partnerships)—were highly intercorrelated, indicating that the internal

Table 8. Multiple Regression Analyses Predicting Collaboration and IBL-Related Factors

Dependent variable	Predictor	Estimate	SE	t	R ²	Adj. R ²
CF1 (Teacher collaboration among colleagues)	SC2 (Middle-Elementary)	-0.052	0.077	-0.68	0.065	0.056
	SC3 (High-Elementary)	-0.434	0.080	-5.46***		
	IBL experience	0.105	0.063	1.67†		
	Gender	0.022	0.077	0.29		
	Age	-0.00002	0.006	-0.00		
	Working Year	0.007	0.005	1.39		
CF2 (Leadership by administrators)	SC2 (Middle-Elementary)	-0.070	0.096	-0.73	0.051	0.042
	SC3 (High-Elementary)	-0.524	0.099	-5.28***		
	IBL experience	0.029	0.079	0.37		
	Gender	-0.078	0.096	-0.81		
	Age	0.002	0.007	0.35		
	Working Year	0.002	0.006	0.33		
CF3 (school-community partnerships)	SC2 (Middle-Elementary)	-0.092	0.075	-1.24	0.069	0.060
	SC3 (High-Elementary)	-0.435	0.077	-5.64***		
	IBL experience	0.134	0.061	2.19*		
	Gender	0.113	0.074	1.53		
	Age	0.004	0.005	0.76		
	Working Year	-0.002	0.005	-0.34		
Overall collaboration	SC2 (Middle-Elementary)	-0.074	0.071	-1.04	0.076	0.067
	SC3 (High-Elementary)	-0.459	0.073	-6.29***		
	IBL experience	0.096	0.058	1.66†		
	Gender	0.032	0.070	0.46		
	Age	0.002	0.005	0.46		
	Working Year	0.002	0.005	0.45		
IBL Network (Teacher network for IBL)	SC2 (Middle-Elementary)	-0.008	0.068	-0.11	0.061	0.052
	SC3 (High-Elementary)	-0.103	0.071	-1.45		
	IBL experience	0.311	0.056	5.57***		
	Gender	-0.005	0.068	-0.08		
	Age	-0.0004	0.005	-0.08		
	Working Year	-0.007	0.005	-1.55		

Note. *p < .05, **p < .01, ***p < .001, †p < .10; N = 650, df = 643.

Table 9. Seemingly Unrelated Regression (SUR) Results for the IBL-Network and Collaboration Equations

Equation	Predictor	Estimate	SE	t	R ²	Adj. R ²
Collaboration (Y = Collaboration)	Intercept	1.060	0.220	4.81***	0.164	0.155
	IBL Network	0.748	0.034	22.02***		
	SC2 (Middle-Elementary)	-0.068	0.064	-1.06		
	SC3 (High-Elementary)	-0.382	0.066	-5.78***		
	IBL experience	-0.137	0.053	-2.57*		
	Gender	0.036	0.064	0.57		
	Age	0.003	0.005	0.58		
	Working Year	0.007	0.004	1.73†		
IBL Network (Y = IBL Network)	Intercept	0.609	0.216	2.82**	0.151	0.141
	Overall Collaboration	0.698	0.032	22.02***		
	SC2 (Middle-Elementary)	0.044	0.062	0.71		
	SC3 (High-Elementary)	0.218	0.065	3.33***		
	IBL experience	0.244	0.051	4.82***		
	Gender	-0.028	0.062	-0.45		
	Age	-0.002	0.005	-0.46		
	Working Year	-0.008	0.004	-2.07*		

Note. †p < .10, *p < .05, **p < .01, ***p < .001. N = 650, df = 642.

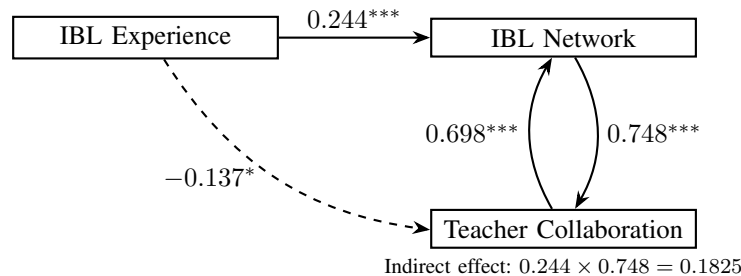


Fig. 1. Reciprocal and Mediated Structure between IBL Experience, Network, and Teacher Collaboration

collaborative culture of schools functions as an integrated whole. In contrast, correlations with the IBL Network were of moderate magnitude, implying that while collaborative culture and the IBL network are connected, they do not overlap completely. In other words, IBL not only extends existing school culture but also expands collaborative relations and forms a layer in which institutional and practical aspects co-act.

By school type, SUR results indicated that internal collaboration tends to be relatively weaker in high schools, whereas participation in the IBL Network (both inside and outside the school) is more active. This pattern may reflect the subject-specialist organizational structure and the institutionalization of the “Period for Inquiry-Based Learning,” which together can catalyze new cross-cutting ties mediated by inquiry [3], [17]. Given the constraints that subject specialization imposes on cross-disciplinary collaboration within high schools, it is plausible that inquiry activities facilitate ties with other schools, local communities, and interdisciplinary partners. Conversely, elementary and middle schools exhibit stronger internal collaborative culture but relatively limited expansion of IBL networks. Taken together, these patterns suggest a trade-off—“high schools: weaker internal collaboration but stronger IBL networks,” “elementary/middle schools: stronger internal collaboration but weaker network expansion.” Thus, IBL networks and cultures are not substitutes for existing collaboration; rather, they function to multiply layers of collaboration within schools.

B. Bidirectional Facilitation and Mediated Structure

The SUR analysis confirmed significant bidirectional effects between collaboration and the IBL network. The effect from collaboration to the IBL network and the reverse effect from the IBL network to collaboration were both strongly positive, suggesting a reciprocal facilitation loop in which intra-school collaborative culture promotes IBL network formation and network activities, in turn, reinforce intra-school culture.

Moreover, IBL teaching experience showed a significant positive effect in the IBL network equation but a significant negative direct effect in the collaboration equation. This difference in signs is not due to computational error but is consistent with a suppression/mediation mechanism: IBL experience promotes collaboration indirectly through the IBL Network (a mediated facilitation structure), rather than directly increasing collaboration. While stand-alone regressions indicated a positive effect of IBL experience on collaboration, in the SUR framework the inclusion of the network variable controls for the indirect pathway, rendering the direct effect relatively negative. Hence, a layered process likely exists in which an IBL experience \rightarrow IBL network \rightarrow Intra-school collaboration mediation pathway coexists with a reciprocal loop collaboration \leftrightarrow IBL network. These results indicate

that the diffusion of IBL proceeds through the joint strengthening of collaborative culture and IBL networks. Notably, even in high schools with subject-specialist constraints, the IBL framework may help generate collaborative communities within schools. Thus, the diffusion of IBL can be viewed not as a mere extension of existing organizational culture but as a process that expands it.

These findings therefore support the existence of a bidirectional facilitation loop between teacher collaboration and the IBL Network: intra-school collaborative culture strengthens IBL networks, and networked inquiry activity re-energizes intra-school culture. Furthermore, school-type differences point to possible hierarchical features linking school culture and network formation (elementary/middle schools being stronger on collaboration; high schools stronger on IBL networking).

An additional possibility is that the negative direct effect reflects the lived reality of early adopters of IBL. Teachers who first implement challenging new practices like IBL may experience isolation from colleagues during the initial phase; they might be perceived as “different,” or their needs may not be recognized by the prevailing school culture. Consequently, their collaborative energy may shift from routine intra-school interactions (e.g., casual exchanges and general information sharing) to professional extra-school networks (e.g., IBL study groups and online communities). This shift could manifest as a negative direct association between IBL experience and collaboration. As their external network activity matures and the knowledge, resources, and legitimacy gained begin to flow back into the school (the positive indirect path via the IBL Network), their practice may then stimulate and elevate the school’s collaborative culture—suggesting a time-lagged, complex process.

Although the high residual correlation ($|r| = 0.879$) indicates a strong coupling between the two equations, it also suggests the possibility of simultaneity. Therefore, while the SUR model provides an efficient estimation of the mutual structure, future research should assess the robustness of these findings using structural equation modeling (SEM), simultaneous equation modeling (e.g., 2SLS), or other rigorous analytical approaches.

C. Practical Implications

Two practical implications follow from these findings for the sustainable diffusion of IBL: (1) mechanisms for forming and maintaining IBL networks (within and beyond schools) should be designed in tandem with efforts to strengthen intra-school collaborative culture; and (2) teachers with IBL practice experience should be positioned as hubs who mediate between school culture and network culture. Integrating these elements at the organizational level is likely

to promote the stable diffusion and development of inquiry culture in schools.

In high schools, where subject specialization is entrenched, it is particularly important to intentionally connect the “external stimulation” provided by IBL networks to the deliberate cultivation of intra-school collaborative culture. This calls for concrete designs for in-school professional development and a reconsideration of leadership roles among administrators.

V. CONCLUSION

This study empirically examined the interrelationship between teacher collaboration and IBL networks among 650 Japanese teachers. The results confirmed a reciprocal facilitation loop: intra-school collaborative culture promotes the formation of IBL networks, and networked activity in turn strengthens collaboration.

However, several limitations remain—most notably, the cross-sectional nature of the data, reliance on self-reports, and limited national scope. Future research should adopt longitudinal and cross-national approaches to further validate this model and explore the dynamics of inquiry culture in diverse contexts. In doing so, we aim to develop an Asia-led model of educational innovation, as suggested by [18].

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