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Participation in tiered collaboration and student self-determined learning outcomes

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ABSTRACT

This study aimed to analyze the influence of student participation in tiered collaboration on self-determined learning (SDL) outcomes among upper-grade elementary school students in Yogyakarta, Indonesia. A quantitative approach with a cross-sectional survey design was employed, involving 860 students selected through stratified random sampling. Data were collected using modified and validated instruments measuring three levels of collaborative participation (peripheral, active, and collaborative leadership) and four dimensions of SDL (autonomous motivation, planning and implementation, self-monitoring, and interpersonal communication). Structural equation modeling (SEM) and cluster analysis using Jamovi software revealed three distinct participation profiles: low (21.2%), moderate (52.6%), and high (26.2%). The results showed that participation in tiered collaboration was positively and significantly associated with on SDL outcomes (β=0.52, $p<0.001$), with active participation contributing the largest effect (β=0.45). Students with high participation profiles achieved significantly higher SDL scores (M=3.48) compared to moderate (M=3.01) and low (M=2.68) profiles. Grade level moderated this relationship, with stronger effects observed in higher grades. The study concludes that structured collaboration is associated with learning autonomy, supporting Indonesia's Merdeka Belajar policy and *gotong royong* cultural values.

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1. INTRODUCTION

Collaborative learning in Indonesian elementary schools faces critical problems that hinder student autonomy. Preliminary observations conducted by the researchers in 15 Yogyakarta elementary schools (January 2024) revealed that 67% of teachers reported only 2–3 students actively contribute per group, and 71% of students admitted to waiting for teacher instructions rather than planning their own work. These findings align with PISA 2022 data, which show that Indonesian students face significant challenges in collaborative learning [1]. The World Bank also confirms learning practices in Indonesia remain teacher-centered, with only 35% of teachers using structured collaborative methods [2]. The root issue is the absence of systematic tiered participation structures.

The transformation from pedagogy to heutagogy has become central to global education reform, with self-determined learning (SDL) placing learners as autonomous agents who determine the direction and evaluation of their learning [3], [4]. In higher education, collaborative projects encourage decision-making and ownership of learning [4], while wikis and digital platforms allow students to jointly build knowledge

and develop autonomy [3], [5]. In Indonesia, the inquiry collaboration project-based learning model is positively associated with learning outcomes compared to traditional methods [6], and the Android-based think-pair-share model is positively associated with understanding of trigonometry when adjusted to students' cognitive styles [7]. These findings align with international research showing that collaborative case-based learning with metacognitive interventions is positively associated with cognitive and social engagement [8], and project-based learning in mobile learning management system (LMS) environments strengthens collaboration skills through self-efficacy [9].

However, the effectiveness of collaboration depends on the quality of interaction. Research in Indonesia reveals that supportive communication and active participation are more important than the mere existence of collaborative activities, emphasizing the integration of local cultural values such as Pancasila and *gotong royong* [10]. Internationally, power dynamics and unequal participation hinder equitable learning outcomes, especially in diverse groups [11]. Wiki-authoring projects show unequal participation correlates with varying outcomes [3]. Pairs produce better grammar learning than larger groups [12]. Cognitive styles influence behavioral patterns in collaborative concept mapping [13]. In massive open online courses (MOOCs), chat-based collaborative activities with self-regulated learning (SRL) interventions improve self-regulation, participation, retention, and outcomes [14], while socially shared metacognition is associated with higher levels of learning [15].

In Indonesia, SDL faces complex challenges. Higher education struggles to develop students' self-determination despite relatively well-supported cognitive and affective aspects [16]. In hybrid learning, instructional and peer support increase satisfaction and performance through intrinsic motivation [17]. Self-regulation and collaborative engagement predict academic outcomes in online higher education [18]. Technology integration and teacher support increase engagement through self-directed learning mediation [19]. Wikis in flipped classrooms increase achievement and satisfaction [5], mobile LMS supports project-based learning and self-efficacy [9], badges increase participation and motivation [20], and alignment of social goals determines computer-supported collaborative learning (CSCL) effectiveness [21]. In this study, SDL is conceptualized as a multidimensional construct comprising four interrelated dimensions: autonomous motivation, planning and implementation, self-monitoring, and interpersonal communication. These dimensions collectively reflect students' capacity to direct, manage, and evaluate their own learning.

Although previous studies have shown that collaborative learning is positively associated with SDL, the process explaining this relationship is still unclear. In this study, tiered collaboration is viewed as a learning process that gradually moves students from peripheral participation to active participation and collaborative leadership. As students participate more actively, they work together to plan, solve problems, monitor progress, and evaluate their learning. These activities reflect socially shared regulation of learning (SSRL), where students regulate learning together. According to self-determination theory (SDT), these collaborative experiences also support students' needs for autonomy, competence, and relatedness. When these needs are fulfilled, students become more motivated, responsible, and able to manage their own learning. Therefore, tiered collaboration is expected to promote higher SDL through shared regulation and the satisfaction of basic psychological needs.

Figure 1 illustrates the proposed theoretical mechanism of this study. Tiered collaboration encourages students to participate actively in shared learning activities, leading to SSRL. These collaborative experiences satisfy students' needs for autonomy, competence, and relatedness, which ultimately support higher levels of SDL.

The literature reveals three fundamental theoretical tensions. First, SDT posits that autonomy develops through gradual release of control [22], [23]. Yet, Indonesian collaborative studies show unstructured group work reinforces dependence on dominant peers [10], [11], and Indonesia's *gotong royong* culture prioritizes collective interdependence [24]. Second, a paradox exists between Western heutagogy models emphasizing individual agency [3], [4], and Indonesia's *gotong royong* culture prioritizing collective interdependence [24], [25]. Third, studies conflict over whether collaboration is associated with higher levels of [15] or with undermining self-regulation [11]. These tensions raise an unresolved question: can structured, tiered participation resolve them by providing a scaffolded pathway from peripheral to leadership roles?

Although previous studies have shown that collaborative learning provides many educational benefits, several research gaps remain. Few studies have identified students' participation profiles using cluster analysis, integrated cluster analysis and structural equation modeling (SEM) in a single framework, or examined these relationships in Indonesian elementary schools. In addition, limited research has investigated whether grade level moderates the relationship between collaborative participation and SDL. Therefore, this study addresses these gaps by examining participation profiles, the relationship between tiered collaboration and SDL, and the moderating role of grade level among Indonesian elementary school students.

This study aims to examine the relationship between participation in tiered collaboration and SDL among upper-grade elementary school students by integrating the perspectives of SSRL and SDT. Specifically, the study proposes that tiered collaboration is related to SDL through progressive participation,

shared regulation, and the satisfaction of students' basic psychological needs. The study also identifies student participation profiles and provides empirical evidence to support the implementation of collaborative learning within Indonesia's Merdeka Belajar policy.

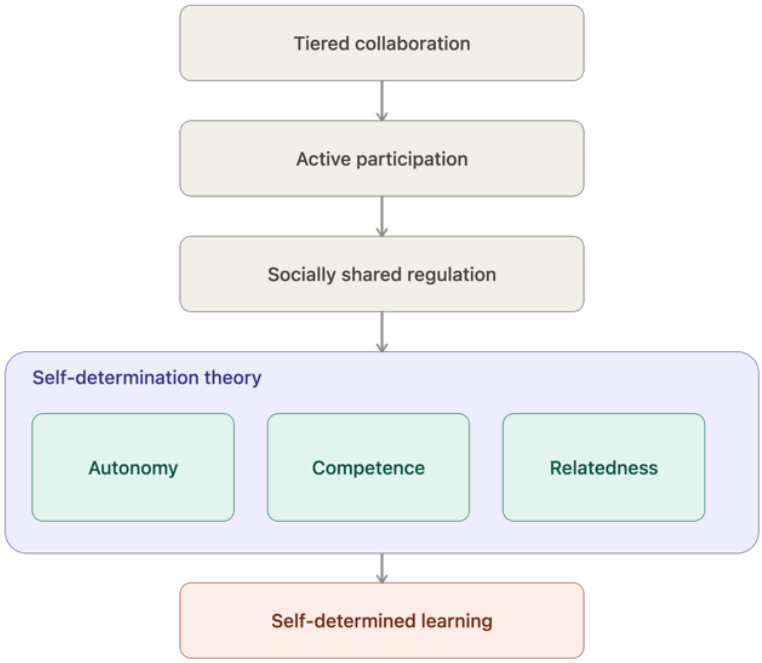


Figure 1. Conceptual model of SDL through tiered collaboration, active participation, and socially shared regulation

2. METHOD

This study uses a quantitative cross-sectional survey design to examine the structural relationship between students' participation in tiered collaboration and SDL outcomes among high-grade elementary school students in Yogyakarta. The cross-sectional design was chosen because it allows the collection of data from large populations over a specific period of time and is effective for identifying causal relationships among latent variables. A quantitative approach with structured surveys is suitable for measuring psychological constructs such as autonomous motivation, self-regulation, and learning agency, which are the main indicators of SDL [21]. To test the structural relationships between latent variables simultaneously, this study uses SEM which combines confirmatory factor analysis (CFA) and path analysis in one integrated framework. Because this study employed a cross-sectional design, the findings should be interpreted as associations between variables rather than evidence of causal relationships.

The target population of this study is all high class students (grades 4, 5, and 6) of elementary schools (SD) in the Special Region of Yogyakarta, with a sample of 860 students taken using stratified random sampling techniques based on class levels and types of schools (public and private). The selection of high-grade elementary school students (ages 9–12 years) is based on Piaget's theory of cognitive development which states that children in the concrete operational stage until the transition to formal operations have the ability to reason logically, classify objects, and understand the perspectives of others, competencies that are essential to participate in multi-level collaboration. Yogyakarta was chosen as the research location because it has unique characteristics as an education city with the highest human development index on the island of Java and is a pilot province for implementing the freedom of learning policy, which emphasizes the development of Pancasila student profiles, especially the independent and cooperative dimensions. The sample size of 860 students exceeded the power analysis recommendation for SEM analysis which requires a minimum of 10 respondents per indicator or 200–500 respondents for models with medium complexity and meets the requirements for maximum likelihood (ML) estimation which requires a minimum sample of 200-400 respondents.

This research instrument was developed by modifying instruments that have been tested and published in internationally reputable journals, and was then adjusted to the characteristics of high-class

elementary school students in Indonesia. All questionnaire items underwent a readability adjustment process for elementary school students. Sentences were simplified, concrete examples were added, and academic terms (e.g., 'autonomous motivation') were explained in age-appropriate language (e.g., 'I can study without being told by the teacher'). A pilot study was conducted with 60 upper-grade elementary school students (grades 4–6) who were not included in the final sample. Based on pilot results, five items were reworded to improve comprehension, and the 4-point Likert scale was confirmed to be well understood by children aged 9–12 years.

The questionnaire on participation in multi-level collaboration (14 items) was modified from the collaborative participation scale [3] by adapting collaborative behavior indicators based on the value of mutual cooperation [8], which operationalized three levels: peripheral participation (4 items), active participation (5 items), and collaborative leadership (5 items). The SDL outcomes questionnaire (20 items) was modified from the SDL scale for elementary students adapted from the theoretical framework of Deci and Ryan [26] and has been validated in the Indonesian context by Suwanda *et al.* [15], with four dimensions: autonomous learning motivation (6 items), planning and implementation (5 items), self-monitoring (4 items), and interpersonal communication (5 items). All statements used a 4-point Likert scale (1=strongly disagree to 4=strongly agree) without a neutral option to avoid central tendency bias in elementary school-age respondents. A 4-point Likert scale (1=strongly disagree to 4=strongly agree) was used without a neutral option to avoid central tendency bias, which is common among child respondents.

The results of the CFA for both instruments indicated that all indicators had good validity and reliability for use with high school students. For the instrument of participation in multi-level collaboration, factor loading values ranged from 0.612 to 0.845, with average variance extracted (AVE) for each dimension: peripheral participation (AVE=0.623), active participation (AVE=0.658), and collaborative leadership (AVE=0.701), all of which exceeded the recommended threshold (≥0.50). Cronbach's alpha values for the three dimensions were 0.814, 0.839, and 0.872, while the composite reliability (CR) values were 0.831, 0.856, and 0.888, respectively, all of which exceeded the threshold of ≥0.70 [27]. For the SDL outcomes instrument, the factor loadings ranged from 0.589 to 0.862, with AVEs for autonomous motivation (0.634), planning and implementation (0.612), self-monitoring (0.598), and interpersonal communication (0.657). Cronbach's alpha values for the four dimensions are 0.846, 0.821, 0.793, and 0.858, while the CR values are 0.852, 0.828, 0.801, and 0.864, respectively. Discriminant validity was also assessed by comparing the square root of each construct's AVE (0.789 to 0.837) with the correlations between constructs (highest r=0.485), thus meeting the Fornell-Larcker criteria.

The questionnaire was administered by the researcher who had been trained for 2×35 minutes per class accompanied by the homeroom teacher to ensure students' understanding of each item. During these sessions, the researcher read each item aloud while students followed along. For difficult items (identified during pilot testing), the researcher provided scripted examples without changing the meaning of the statement. Data analysis was carried out using Jamovi (version 2.6) with the structural equation modeling using the Jamovi Module (SEMLj Module), based on the lavaan package in R, which performs covariance-based structural equation modeling (CB-SEM) estimation using ML. Prior to the structural analysis, K-means clustering was performed to classify students according to their participation in tiered collaboration. Several cluster solutions (k=2–6) were evaluated using the silhouette coefficient, Calinski–Harabasz index, and Davies–Bouldin index. Although the two-cluster solution showed slightly better statistical performance, the three-cluster solution was retained because it was theoretically more consistent with the tiered collaboration framework and provided meaningful educational profiles representing low, moderate, and high participation. The resulting cluster membership was subsequently used for descriptive and comparative analyses.

SDL was modeled as a second-order construct comprising four dimensions: autonomous motivation, planning and implementation, self-monitoring, and interpersonal communication. This approach allows the four dimensions to collectively reflect the overall SDL construct while maintaining the conceptual distinction between the construct and its indicators. The structural model examined the direct effects of the three dimensions of tiered collaboration participation (peripheral, active, and collaborative leadership) on the second-order SDL construct. The analysis procedure included: i) assessment of measurement model fit through CFA; ii) specification of the structural model based on the theoretical framework; iii) estimation of model parameters using the ML method; iv) goodness-of-fit evaluation using the following criteria: $\chi^2/df \leq 3$, comparative fit index (CFI)≥0.90, Tucker-Lewis index (TLI)≥0.90, root mean square error of approximation (RMSEA)≤0.08, and standardized root mean square residual (SRMR)≤0.08 [28]; and v) testing the significance of path coefficients using the Z (critical ratio) test with a significance level of $\alpha=0.05$. No data were missing because each questionnaire was checked for completeness immediately after administration. Additionally, Harman's single-factor test was conducted to assess common method bias; the first factor explained 28.7% of the total variance, below the 50% threshold, indicating that common method bias was not a serious threat [29].

3. RESULTS AND DISCUSSION

3.1. Demographic characteristics of respondents

Of the 860 upper-grade elementary school students who participated in this study, all returned complete questionnaires, yielding a 100% response rate. The demographic characteristics of respondents included gender, grade level, school type, age, and parental education background. The gender distribution was relatively balanced, with 420 male students (48.8%) and 440 female students (51.2%). By grade level, the distribution was equitable, with 280 students in grade 4 (32.6%), 290 in grade 5 (33.7%), and 290 in grade 6 (33.7%). Regarding school type, 516 students (60.0%) attended public elementary schools, while 344 students (40.0%) attended private elementary schools in the Yogyakarta region. Respondents' ages ranged from 9 to 13 years, with a mean age of 10.8 years (SD=1.12), where the majority of students were aged 10 years (28.5%), followed by 11 years (26.7%), 9 years (22.4%), 12 years (17.8%), and 13 years (4.6%). Table 1 presents the complete demographic characteristics of the respondents.

Table 1. Demographic characteristics of respondents (N=860)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	420	48.8
	Female	440	51.2
Grade level	Grade 4	280	32.6
	Grade 5	290	33.7
	Grade 6	290	33.7
School type	Public school	516	60.0
	Private school	344	40.0
Age	9 years	193	22.4
	10 years	245	28.5
	11 years	230	26.7
	12 years	153	17.8
	13 years	39	4.6
Father's education	Elementary or equivalent	129	15.0
	Junior high or equivalent	206	24.0
	Senior high or equivalent	301	35.0
	Diploma/bachelor's degree	224	26.0
Mother's education	Elementary or equivalent	146	17.0
	Junior high or equivalent	215	25.0
	Senior high or equivalent	292	34.0
	Diploma/bachelor's degree	207	24.0
School location	Urban	602	70.0
	Suburban	258	30.0

3.2. Descriptive statistics of research variables

Descriptive statistics indicated that students' overall participation in tiered collaboration was moderate, whereas SDL outcomes were generally higher. Among the participation dimensions, active participation scored the highest, whereas peripheral participation and collaborative leadership were at moderate levels. For SDL, autonomous motivation and interpersonal communication were in the high category, while planning and implementation and self-monitoring fell within the moderate range. The Shapiro-Wilk test of normality indicated that all variable data were normally distributed ($p>0.05$), with skewness values ranging from -0.42 to 0.38 and kurtosis values ranging from -0.35 to 0.52, which fall within acceptable ranges for parametric analysis. Table 2 presents the complete descriptive statistics of all research variables.

Table 2. Descriptive statistics of all research variables (N=860)

Variable/dimension	Items	Min	Max	Mean (M)	SD	Skewness	Kurtosis	Category
Tiered collaboration participation	14	1.21	4.00	2.87	0.52	-0.28	0.35	Moderate
Peripheral participation	4	1.00	4.00	2.71	0.59	-0.15	0.28	Moderate
Active participation	5	1.20	4.00	3.12	0.48	-0.42	0.52	High
Collaborative leadership	5	1.00	4.00	2.79	0.61	-0.18	0.31	Moderate
SDL outcomes	20	1.25	4.00	3.05	0.44	-0.35	0.42	High
Autonomous motivation	6	1.00	4.00	3.24	0.45	-0.38	0.48	High
Planning and implementation	5	1.00	4.00	3.01	0.50	-0.22	0.35	Moderate
Self-monitoring	4	1.00	4.00	2.86	0.54	-0.12	0.24	Moderate
Interpersonal communication	5	1.00	4.00	3.08	0.51	-0.31	0.39	High

Category: 1.00-1.75=Very low; 1.76-2.50=Low; 2.51-3.25=Moderate; 3.26-4.00=High

These descriptive findings indicate that students with higher participation in tiered collaboration tended to report higher SDL outcomes. However, as this study used a cross-sectional design, these patterns should be interpreted as positive associations rather than causal effects. Based on the results of the descriptive statistical analysis, student participation in multi-level collaboration is, overall, in the medium category (M=2.87; SD=0.52). Interestingly, the active participation dimension obtained the highest score (M=3.12; SD=0.48) which belongs to the high category. These findings are in line with the cultural value of mutual cooperation that is taught from an early age in Indonesian society [27], [30]. These values encourage children to be actively involved in group work, both through community traditions such as Marsiadapari and project-based learning at school [31]. However, the collaborative leadership dimension only achieved a moderate score (M=2.79; SD=0.61), lower than active participation. This confirms the view that although children are encouraged to contribute in groups, collaborative leadership roles are still often considered more appropriate for older adults or students [9], [32]. In other words, children's active participation in mutual cooperation has not necessarily been followed by recognition of their own leadership capacity.

Furthermore, SDL outcomes showed higher overall scores (M=3.05; SD=0.44) in the high category. The autonomous motivation dimension recorded the highest score (M=3.24; SD=0.45), followed by interpersonal communication (M=3.08; SD=0.51). This indicates that internalizing the value of mutual cooperation can foster motivational independence and interpersonal communication skills, which are important foundations for healthy cooperation. However, the dimensions of planning and implementation (M=3.01; SD=0.50) and self-monitoring (M=2.86; SD=0.54) is only in the medium category. This low self-monitoring score reflects a broader challenge: collaborative leadership in Indonesian culture is still perceived hierarchically, with decision-making and primary responsibility often falling to teachers or older students [33]. Thus, although mutual cooperation fosters active participation and autonomous motivation, the development of collaborative leadership and self-regulation in children still requires pedagogical interventions that explicitly train joint planning, monitoring, and decision-making skills within a cultural framework that respects local values.

3.3. Student participation profiles through cluster analysis

Before conducting the final K-means cluster analysis, several cluster solutions (k=2–6) were evaluated using internal validation indices, including the silhouette coefficient, Calinski–Harabasz index, and Davies–Bouldin index. The results of these alternative cluster solutions are presented in Table 3. Based on a combined evaluation of statistical evidence and theoretical interpretability, the three-cluster solution was selected because it best represented the conceptual progression of tiered collaboration from low to moderate to high participation. This solution also provided meaningful educational profiles for subsequent analyses.

Table 3. Evaluation of alternative cluster solutions

Number of clusters	Silhouette	Calinski–Harabasz	Davies–Bouldin
2	0.433	1040.29	0.832
3	0.375	1022.24	0.888
4	0.308	909.07	1.048
5	0.272	806.17	1.163
6	0.275	749.57	1.128

Based on the final K-means cluster analysis conducted in Jamovi, 860 students were classified into three significantly different participation profiles ($F(2,857)=847.32$, $p<0.001$). The first profile, low participation (n=182, 21.2%), had a mean score of 2.12 (SD=0.31) and was characterized by passive participation with limited contribution during collaborative activities. The second profile, moderate participation (n=452, 52.6%), represented the largest group, with a mean score of 2.89 (SD=0.28), reflecting balanced participation while still relying on peer direction. The third profile, high participation (n=226, 26.2%), achieved the highest mean score (M=3.45, SD=0.29) and demonstrated consistent active engagement, initiative, and collaborative leadership. These findings indicate that students formed three distinct participation profiles that reflect different levels of engagement in tiered collaboration.

The three participation profiles indicate that students differ not only in the frequency of collaborative engagement but also in the quality of their participation during learning activities. Students in the high participation profile were more likely to take initiative, coordinate group activities, and contribute to shared problem-solving, whereas students in the low participation profile tended to participate passively and rely on peers. This pattern is consistent with the concept of SSRL, which emphasizes that effective collaboration develops through shared planning, monitoring, and evaluation among group members. As students become more actively involved in these regulatory processes, they are more likely to develop learning autonomy and responsibility. These findings suggest that collaborative participation should be

viewed as a developmental process rather than a fixed characteristic. Therefore, teachers need to provide structured collaborative experiences that progressively encourage students to move from peripheral participation toward collaborative leadership.

The demographic distribution of the three participation profiles revealed several meaningful patterns. Female students were more likely to belong to the high participation profile (54.0%), whereas male students were more likely to be classified in the low participation profile (55.5%). In addition, the proportion of students with high participation increased across grade levels, from grade 4 (23.5%) to grade 6 (41.6%), suggesting that collaborative participation develops with age and learning experience. Students from private schools also showed a higher proportion of high participation (47.4%) than those from public schools (52.6% in public vs. 47.4% in private within the high-participation group), indicating possible differences in learning environments that support collaborative engagement. These findings reflect that although the school system in Yogyakarta is quite successful in introducing and facilitating collaborative learning [30], it has not been optimal in encouraging students to achieve the highest level of participation, as only 26.2% of students fall under the high participation profile. Most students (52.6%) were at a moderate level of participation, indicating a balance between active engagement and reliance on peer direction, while the remaining 21.2% showed passive participation [34], [35].

The distribution of the three participation profiles across demographic characteristics reveals interesting patterns. The detailed distribution of participation profiles according to gender, grade level, school type, and school location is presented in Table 4, while the overall distribution of the three participation profiles is illustrated in Figure 2. Male students were more likely to be found in a low participation profile (55.5%), while female students were more likely to be found in a high participation profile (58.4%). Furthermore, higher grade levels were associated with a greater proportion of students on high participation profiles (4th grade: 18.9%; 5th grade: 27.2%; 6th grade: 32.4%). In addition, students from private schools have a higher proportion of high participation profiles (31.4%) than public school students (23.1%). These findings are in line with previous research showing that uneven participation in collaborative learning is common, where some students dominate while others contribute minimally [25], [36]. Cultural and contextual factors also play a role, where collaborative learning outcomes are strongly influenced by group dynamics, students' initial knowledge, and learning environment design [36], [37]. Therefore, more targeted interventions are needed, including better teacher training, a more balanced group dynamics structure, and technology-based approaches to increase student active participation, especially in male groups and students from public schools who still dominate low participation profiles [34], [38].

Table 4. Distribution of participation profiles based on demographic characteristics

Characteristic	Category	Low participation (n=182)	Moderate participation (n=452)	High participation (n=226)
Gender	Male	101 (55.5%)	215 (47.6%)	104 (46.0%)
	Female	81 (44.5%)	237 (52.4%)	122 (54.0%)
Grade level	Grade 4	80 (44.0%)	147 (32.5%)	53 (23.5%)
	Grade 5	58 (31.9%)	153 (33.8%)	79 (34.9%)
	Grade 6	44 (24.1%)	152 (33.7%)	94 (41.6%)
School type	Public school	126 (69.2%)	271 (60.0%)	119 (52.6%)
	Private school	56 (30.8%)	181 (40.0%)	107 (47.4%)
School location	Urban	112 (61.5%)	312 (69.0%)	178 (78.8%)
	Suburban	70 (38.5%)	140 (31.0%)	48 (21.2%)

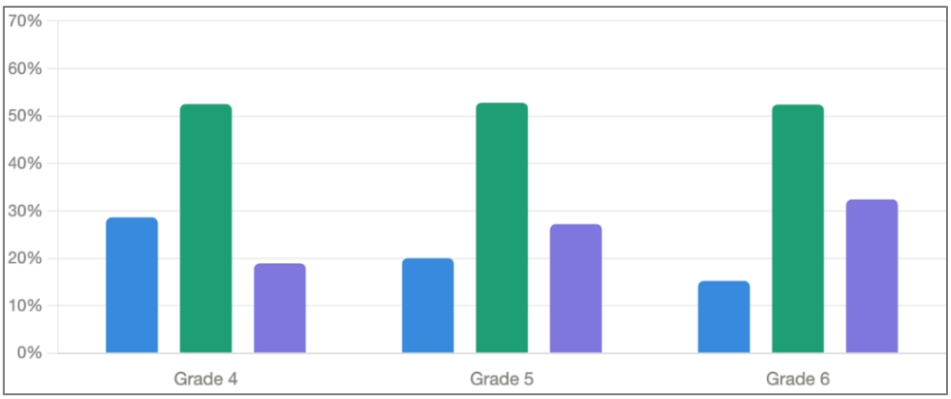


Figure 2. Distribution of student participation profiles in tiered collaboration (N=860)

3.4. Differences in self-determined learning outcomes across participation profiles

To examine whether SDL differed across the three participation profiles, a one-way analysis of variance (ANOVA) was performed. The results showed statistically significant differences among the low-, moderate-, and high-participation groups across all dimensions of SDL, including autonomous motivation, planning and implementation, self-monitoring, interpersonal communication, and overall SDL. As presented in Table 5, students in the high participation profile consistently achieved the highest mean scores across all dimensions of SDL, whereas students in the low participation profile obtained the lowest scores. The moderate participation group demonstrated intermediate scores, indicating a progressive increase in SDL as students became more actively involved in tiered collaborative learning.

ANOVA results revealed significant differences in SDL outcomes across the three participation profiles with a large effect size ($F(2,857)=124.63$, $p<0.001$, $\eta^2=0.225$). Post hoc comparisons confirmed that higher participation profiles were associated with progressively higher SDL scores. Further analysis of each SDL outcomes dimension showed a consistent pattern, where students with high participation consistently obtained the highest scores across all dimensions. The largest difference was found in the autonomous motivation dimension ($F=98.45$, $p<0.001$, $\eta^2=0.187$), while the smallest difference was found in the interpersonal communication dimension ($F=45.67$, $p<0.001$, $\eta^2=0.096$). Table 5 compares scores across participation profiles for each dimension, while Figure 3 visualizes these comparisons. Figure 3 illustrates the progressive increase in SDL across the three participation profiles. The graphical pattern demonstrates a consistent improvement in all dimensions of SDL from the low- to the high-participation group, indicating that higher levels of collaborative participation are associated with stronger autonomous learning behaviors.

The one-way ANOVA results showed statistically significant differences in SDL outcomes across the three participation profiles ($F(2,857)=124.63$, $p<0.001$, $\eta^2=0.225$). The large effect size ($\eta^2=0.225$, exceeding Cohen's threshold of 0.14 for a large effect) indicates that participation profile membership is substantially associated with SDL outcomes. Post hoc comparisons confirmed that higher participation profiles were associated with progressively higher SDL scores. Importantly, these findings demonstrate an association between participation level and SDL outcomes. Due to the cross-sectional design, we cannot conclude that higher participation causes better SDL; rather, the two variables co-occur in a systematic pattern.

The one-way ANOVA in Jamovi revealed statistically significant differences in SDL outcomes among the three student participation profiles ($F(2,857)=124.63$, $p<0.001$, $\eta^2=0.225$). Students with a high participation profile achieved the highest SDL outcome score ($M=3.48$, $SD=0.31$), followed by students with a moderate participation profile ($M=3.01$, $SD=0.38$), and students with a low participation profile ($M=2.68$, $SD=0.43$). The post hoc Tukey HSD test showed that all pairwise differences were significant ($p<0.001$). These findings reinforce the argument that structured collaboration drives the development of self-regulation and learning agency [23], [24]. The higher the level of student participation in collaboration, the greater their ability to manage learning independently. This is in line with the concept of SSRL which states that co-regulation in collaborative groups is associated with higher levels of regulatory strategies for both individuals and groups, which in turn encourages deeper engagement and a greater sense of responsibility [36].

Further analysis of each self-determined dimension of learning outcomes showed a consistent pattern, where students with high participation consistently obtained the highest scores across all dimensions. The largest differences were found in the dimensions of autonomic motivation ($F=98.45$, $p<0.001$, $\eta^2=0.187$), while the smallest differences were found in the dimensions of interpersonal communication ($F=45.67$, $p<0.001$, $\eta^2=0.096$). These findings indicate that structured collaboration specifically has the most significant impact on students' autonomous motivation, i.e. the ability to orient themselves in learning without relying on external direction. This supports previous research showing that structured collaboration creates an environment that is related to autonomy and shared responsibility [39], [40]. In addition, the use of tools such as self-assessment templates and individual preparation prior to collaboration has been shown to deepen engagement in regulatory behaviors and encourage proactive learning strategies [39], [41]. Thus, interventions designed to increase student participation from low- and medium-profile to high-profile are highly recommended, as this will directly improve autonomous motivation and overall SDL outcomes [42], [43].

Table 5. Comparison of SDL outcomes across participation profiles

SDL dimension	Low profile (n=182) M (SD)	Moderate profile (n=452) M (SD)	High profile (n=226) M (SD)	F	p	η^2
Autonomous motivation	2.89 (0.48)	3.24 (0.39)	3.58 (0.31)	98.45	<0.001	0.187
Planning and implementation	2.62 (0.52)	3.01 (0.44)	3.35 (0.39)	87.23	<0.001	0.169
Self-monitoring	2.48 (0.58)	2.86 (0.48)	3.19 (0.44)	76.89	<0.001	0.152
Interpersonal communication	2.73 (0.56)	3.08 (0.46)	3.41 (0.38)	45.67	<0.001	0.096
SDL total	2.68 (0.43)	3.01 (0.38)	3.48 (0.31)	124.63	<0.001	0.225

Note: η^2=effect size (small=0.01; medium=0.06; large=0.14)

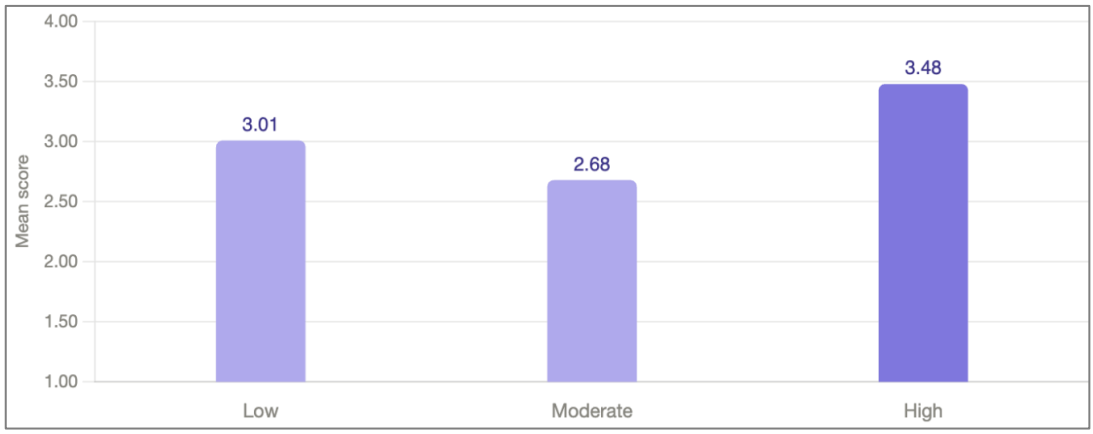


Figure 3. Comparison of SDL outcomes scores across participation profiles

3.5. Assumption testing and measurement model evaluation

Before testing the hypothesized structural relationships, the measurement model was evaluated to ensure that all constructs demonstrated adequate reliability and validity. Reliability was assessed using Cronbach's alpha and CR, while convergent validity was evaluated based on standardized factor loadings and AVE. The results of the measurement model evaluation are presented in Table 6.

Table 6 summarizes the reliability and validity of the measurement model. All constructs demonstrated satisfactory psychometric properties. Factor loadings ranged from 0.589 to 0.862, exceeding the recommended threshold of 0.50. CR values ranged from 0.801 to 0.888, and Cronbach's alpha coefficients ranged from 0.793 to 0.872, indicating good internal consistency. In addition, all AVE values were above the recommended threshold of 0.50, confirming adequate convergent validity. Overall, these results indicate that the measurement model met the recommended reliability and validity criteria and was suitable for subsequent structural model analysis. As shown in Table 7, all goodness-of-fit indices met the recommended criteria, indicating that both the measurement and structural models adequately fit the observed data. Therefore, the proposed model was considered appropriate for testing the hypothesized relationships among the study variables.

Table 6. Reliability and validity of the measurement model

Construct	Loading	AVE	CR	Alpha
Peripheral participation	0.612–0.845	0.623	0.831	0.814
Active participation	0.631–0.827	0.658	0.856	0.839
Collaborative leadership	0.684–0.845	0.701	0.888	0.872
Autonomous motivation	0.612–0.862	0.634	0.852	0.846
Planning and implementation	0.601–0.834	0.612	0.828	0.821
Self-monitoring	0.589–0.805	0.598	0.801	0.793
Interpersonal communication	0.635–0.854	0.657	0.864	0.858

Table 7. Summary of measurement model goodness-of-fit

Criterion	Obtained value	Cut-off value	Status
χ^2/df	2.34	≤3.00	Fit
CFI	0.945	≥0.90	Fit
TLI	0.936	≥0.90	Fit
RMSEA	0.058	≤0.08	Fit
SRMR	0.052	≤0.08	Fit
AGFI (adjusted goodness of fit index)	0.901	≥0.90	Fit
NFI (normed fit index)	0.928	≥0.90	Fit

Prior to conducting a SEM analysis using the Jamovi SEMLj module, assumption testing was performed, and the results indicated that the data met the requirements for maximum-likelihood estimation. Mardia's test indicated multivariate normality, and variance inflation factor (VIF) values confirmed no multicollinearity. CFA demonstrated good validity and reliability across all indicators, with standardized factor loadings ranging from 0.58 to 0.86 ($p<0.001$ for all indicators). The measurement model achieved

good fit across all criteria (Table 7). All these values met the recommended goodness-of-fit criteria ($\chi^2/df \leq 3$, CFI≥0.90, TLI≥0.90, RMSEA≤0.08, SRMR≤0.08), indicating that the measurement model was acceptable for proceeding with structural model analysis [28]. Table 7 presents a summary of the measurement model goodness-of-fit evaluation.

3.6. Structural model analysis, hypothesis testing, and summary of findings

The structural equation model demonstrated a satisfactory fit to the data, indicating that the proposed model adequately represented the relationships among the study variables. The standardized path coefficients showed that all three dimensions of tiered collaboration significantly predicted SDL. Among these dimensions, collaborative leadership exhibited the strongest positive effect, followed by active participation and peripheral participation.

The structural model analysis using SEM in Jamovi showed that the hypothesized model had a good fit ($\chi^2/df=2.56$, CFI=0.938, TLI=0.929, RMSEA=0.062, SRMR=0.056). SDL was modeled as a second-order construct comprising four dimensions: autonomous motivation, planning and implementation, self-monitoring, and interpersonal communication. Hypothesis testing revealed that participation in tiered collaboration had a positive and significant effect on SDL outcomes ($\beta=0.52$, SE=0.04, $z=13.45$, $p<0.001$). Further analysis of each participation dimension showed that active participation had the largest effect on SDL outcomes ($\beta=0.45$, $p<0.001$), followed by collaborative leadership ($\beta=0.31$, $p<0.001$), while peripheral participation showed a smaller but still significant effect ($\beta=0.18$, $p=0.003$). The R^2 value for SDL outcomes was 0.482, indicating that 48.2% of the variance in SDL outcomes could be explained by the three dimensions of tiered collaboration participation. Regarding moderation effects, a multi-group SEM analysis using Jamovi revealed no significant moderation effect of gender ($\Delta\chi^2=3.42$, $p=0.182$), but a significant moderation effect of grade level ($\Delta\chi^2=18.76$, $p=0.001$). Specifically, the effect of collaborative participation on SDL outcomes increased with higher grade level (grade 4: $\beta=0.41$; grade 5: $\beta=0.53$; grade 6: $\beta=0.62$). Table 8 summarizes all hypothesis-testing results, while Figure 4 presents the complete structural model with path coefficients.

The moderating role of grade level in the collaboration-SDL relationship aligns with developmental theories of metacognition and self-regulation. Research consistently shows that metacognitive and self-regulatory abilities strengthen with age, with significant growth as children progress through elementary school [44]. This developmental trajectory explains why older students (grade 6) demonstrated stronger associations compared to younger students (grade 4): more advanced metacognitive monitoring enables older children to better internalize collaborative leadership roles and translate participation into SDL behaviors.

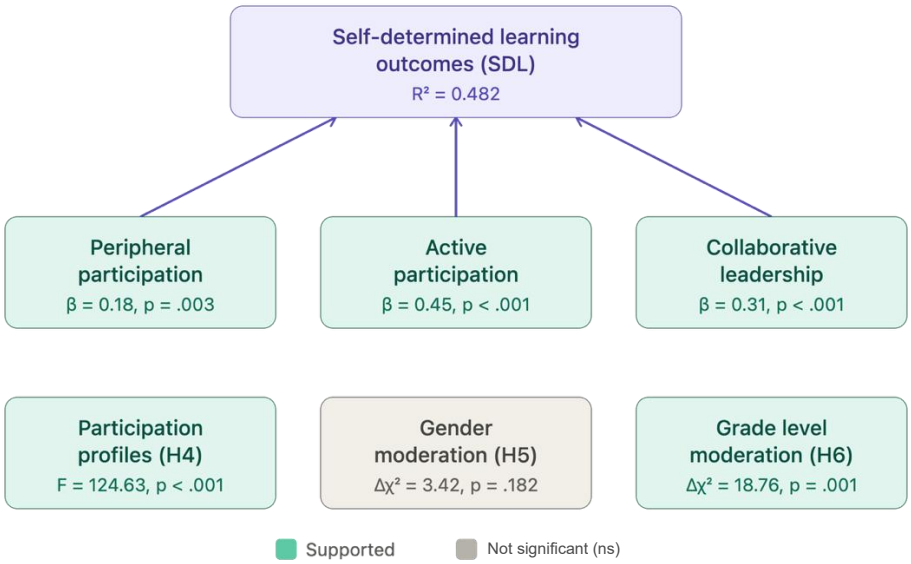
Beyond classroom practice, the findings also have broader educational implications. School leaders can support the implementation of tiered collaborative learning by providing professional development opportunities and fostering a school culture that values collaborative learning. Curriculum developers may incorporate tiered collaboration into instructional guidelines to strengthen students' SDL competencies. Teacher education institutions should prepare prospective teachers to facilitate collaborative learning that promotes active participation and shared regulation. At the policy level, these findings support the implementation of the Merdeka Belajar curriculum, which emphasizes student-centered learning, collaboration, and learner autonomy.

The findings can be explained by integrating SSRL and SDT. As students participated more actively in tiered collaboration, they engaged in shared planning, problem-solving, and monitoring of learning activities, reflecting the process of socially shared regulation. These collaborative experiences likely supported students' needs for autonomy, competence, and relatedness. When these psychological needs were fulfilled, students became more motivated and responsible for managing their own learning, leading to higher levels of SDL. This finding supports the conceptual framework proposed in Figure 1. This finding is consistent with previous research showing that older students outperform their younger peers on tasks requiring abstract reasoning and inference. These findings align with the Indonesian context as well, where SRL positively influences learning outcomes in elementary education settings.

Table 8. Summary of hypothesis testing results

No.	Hypothesis	Coefficient (β)	SE	z	p	95% CI	Decision
H1	Peripheral participation → SDL outcomes	0.18	0.06	2.98	0.003	[0.06; 0.30]	Supported
H2	Active participation → SDL outcomes	0.45	0.05	9.21	<0.001	[0.35; 0.55]	Supported
H3	Collaborative leadership → SDL outcomes	0.31	0.05	6.45	<0.001	[0.21; 0.41]	Supported
H4	SDL differences across participation profiles	F=124.63	-	-	<0.001	-	Supported
H5	Moderation of gender	$\Delta\chi^2=3.42$	-	-	0.182	-	Not supported
H6	Moderation of grade level	$\Delta\chi^2=18.76$	-	-	0.001	-	Supported

Note: SE=standard error; CI=confidence interval



Note: SDL was modeled as a second-order construct comprising four dimensions: autonomous motivation, planning and implementation, self-monitoring, and interpersonal communication. Standardized path coefficients are shown. All paths are significant at p<0.01.

Figure 4. Structural model of the relationship between tiered collaboration participation and SDL outcomes (second-order construct)

4. CONCLUSION

This study demonstrates that tiered collaboration is a significant predictor of SDL among upper elementary school students. Students with higher levels of collaborative participation, particularly those who assumed collaborative leadership roles, exhibited stronger autonomous motivation, learning planning, self-monitoring, and interpersonal communication. The cluster analysis further identified three distinct participation profiles: low, moderate, and high participation, indicating that collaborative engagement develops progressively rather than uniformly among students.

The findings provide theoretical evidence that the relationship between tiered collaboration and SDL can be understood by integrating SSRL and SDT. Active collaborative participation enables students to collectively regulate learning through shared planning, monitoring, and evaluation, while simultaneously supporting their basic psychological needs for autonomy, competence, and relatedness. These processes contribute to the development of more autonomous and self-directed learners. From a practical perspective, the findings suggest that elementary school teachers should design collaborative learning activities that progressively encourage students to move from peripheral participation toward active participation and collaborative leadership. Such learning environments may strengthen both collaborative competence and SDL.

These findings also provide practical guidance for school leaders, curriculum developers, teacher education institutions, and education policymakers to strengthen collaborative and student-centered learning, particularly in implementing the Merdeka Belajar curriculum. This study is limited by its cross-sectional design, which does not permit causal inference, and by its focus on upper elementary school students in Yogyakarta, which limits the generalizability of the findings. Future research is recommended to employ longitudinal or experimental designs, examine the mediating role of socially shared regulation, and validate the proposed participation profiles across different educational levels and cultural contexts.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
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P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

To ensure fair and objective decision-making, the authors declare any associations that pose a conflict of interest (financial, personal, or professional) in connection with this manuscript. The research was conducted solely for scientific and educational advancement, free from any external bias or commercial pressure. Therefore, the authors state that they have no conflicts of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study. Prior to the commencement of data collection, written informed consent was obtained from the parents or legal guardians of all participating elementary school students after they had been fully informed about the purpose, procedures, potential risks, and benefits of the research. The informed consent form clearly stated that participation was entirely voluntary, that respondents could withdraw at any time without any consequences, and that all data would be kept strictly confidential and used solely for academic research purposes. All consent documents have been securely stored by the research team and are available for review upon request by the journal or relevant ethics committees.

ETHICAL APPROVAL

This study received ethical approval from the Research Ethics Committee of Universitas PGRI Yogyakarta (Certificate No. A.004/KEP-UPY/IV/2026, dated April 30, 2026), valid through April 30, 2027. All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [AS], upon reasonable request. Due to the nature of the research involving human subjects, particularly underage participants, and to protect their privacy and confidentiality as approved by the institutional ethics committee, the raw data are not publicly available. The informed consent agreements signed by the parents or legal guardians of the participants explicitly guaranteed that all personal information and individual responses would remain confidential and would not be shared in any publicly accessible repository.

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