



Network analysis of Chinese and Finnish students' social-emotional skills: A cross-cultural comparative study

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Received: 18 November 2025; Accepted: 18 May 2026; Published: 31 August 2026

Abstract: Social-emotional skills (SES) are foundational to academic success and well-being, yet limited research has examined how these skills are structurally organized as an interconnected system across cultural contexts. Drawing on data from the 2023 OECD Survey on Social and Emotional Skills (SSES; 48.97% females, mean age = 13.09, SD = 2.21 years). Results from Gaussian Graphical Models (GGM) identify optimism and curiosity as universal hub nodes across both cultural contexts. Culturally, the Chinese SES network exhibits higher connectivity and integration, with the Emotional Regulation domain serving as a primary organizational anchor. In contrast, the Finnish network displays a more differentiated structure, with the Engaging with Others domain showing stronger central connectivity. Developmentally, the transition from children (age 10) to adolescence (age 15) is associated with significant network consolidation, as indicated by increased global strength in both contexts. Gender differences are reflected in distinct centrality patterns: male students prioritize Stress Resistance and Emotional Control as key nodes, while female students show stronger integration between Collaboration and Task Performance domains. Socioeconomic status (SESs) was associated with culturally contingent centrality patterns. Low-SESs Chinese students' networks were more strongly anchored by Emotional Regulation and Task Performance facets, whereas low-SESs Finnish students showed higher centrality in Open-Mindedness facets. Consistent with Stage-Environment Fit theory, these findings indicate how cultural context, developmental stage, gender, and socioeconomic resources shape the structural organization of SES, providing theoretical insights for culturally responsive social-emotional education.

Keywords: Social-emotional skill; network analysis; cross-cultural study; SSES 2023; adolescent development

Introduction

A substantial body of research indicates that higher Social-emotional skill (SES) is associated with better academic achievement (Zhao & Sang, 2025; Durlak et al., 2011), improved mental health and well-being (Taylor et al., 2017; Durlak et al., 2022; Wang & King, 2025), and more favorable long-term outcomes in education, employment, and career success (Jones et al., 2015; Parmentier et al., 2019). SES refers to an individual's integrated capacity to navigate social environments, regulate emotions, and manage goal-directed behaviors (Collie, 2022; OECD, 2015; Soto et al., 2022). Past studies have examined mean-level differences in SES scores across different cultural settings (OECD, 2021). However, less work has investigated how cultural contexts are associated with the topological organization of SES networks. In addition, existing cross-cultural research on SES has primarily examined age-related changes in skill scores without exploring how the network structure differs between children (age 10) and adolescents (age 15). More recent work emphasizes that SES comprises multiple interrelated skill dimensions; examining only mean-level differences presents an incomplete picture of how these skills function as a system (Soto et al., 2022; Huo & Ning, 2025a). Furthermore, while score disparities across gender and

socioeconomic status groups have been well documented, limited attention has been directed toward understanding how these demographic factors relate to the topological organization of SES networks from a systems perspective.

To address these gaps, this research examines how SES networks differ across Western and Eastern cultural contexts, developmental stages, gender, and socioeconomic status. This approach facilitates a more nuanced understanding of social-emotional development by moving beyond score-based assessments to identify the structural mechanisms underlying how SES functions as an integrated system.

Networked social-emotional skill (SES) by culture

Culture is a key contextual lens through which social-emotional skills (SES) are socialized, expressed, and evaluated in childhood and adolescence (Ren & Wyver, 2014, 2016). A growing body of cross-cultural work shows that cultural value orientations—especially individualism and collectivism—shape both the development of SES and their adaptive meaning. In more collectivistic contexts, stronger endorsement of collectivist values is linked to warmer parenting, expectations for family obligation, better child adjustment, and lower externalizing problems, partly via social support and group cohesion. In contrast,



higher individualism is associated with viewing children as self-reliant and independent, and can relate to more child behavior problems in some settings (Gorla et al., 2024).

These value differences are reflected in emotion regulation and socialization practices. Endorsing collectivist values is associated with greater use of cognitive reappraisal, which in turn predicts better school adaptation and fewer depressive symptoms among Chinese minority students, whereas individualism is linked to expressive suppression and poorer adjustment (Zhao & Hu, 2024). Across seven countries, individual differences in individualism–collectivism (including vertical/horizontal forms) show robust associations with preferred emotion regulation strategies, indicating that how young people manage and display emotions is systematically tied to their cultural value orientations (Klein et al., 2024). Moreover, collectivist orientations emphasizing interdependence and harmony are associated with obedience, respect for family obligations, and conformity in parenting, while more individualist orientations are linked to granting autonomy and encouraging independent decision-making (Gorla et al., 2024).

Sociodemographic moderation

Age is a fundamental determinant of SES, closely linked to changes in cognitive, biological, and social environments. The transition from childhood (around age 10) to adolescence (around age 15) is recognized as a sensitive period during which SES undergoes mean-level fluctuations and structural reconfigurations (Chernyshenko et al., 2018).

Gender serves as a significant factor shaping SES development, reflecting the interaction between biological maturation and cultural expectations. Gender socialization theories suggest that developmental outcomes are linked to adherence to traditional gender roles, which guide children and adolescents toward distinct functional priorities (Brody, 1999). For adolescent males, social expectations emphasize emotional stoicism and self-reliance, leading to an SES organization that prioritizes Emotional Regulation as a functional coping mechanism. For adolescent females, socialization toward communal values and interpersonal nurturance results in high integration between Collaboration and Task Performance domains. Evidence supports these gendered patterns: network analysis identifies regulatory skills as critical bridge nodes for resilience among adolescent males (Guo et al., 2023), while longitudinal studies show that empathy-related traits and prosocial behavior are more consistently reinforcing for girls (Van der Graaff et al., 2018). These patterns are further shaped by role intensification during mid-adolescence, where developmental path distinctiveness correlates with local gender egalitarianism (Hill & Lynch, 1983).

Socioeconomic status (SESs) functions as a critical contextual factor shaping the organization of students' social-emotional skills. Within the Conservation of Resources theory (Hobfoll, 1989), socioeconomic resources influence how individuals allocate and protect psychological capital. Those in resource-constrained environments may prioritize internal regulatory capacities, whereas those in resource-rich settings may develop

more diversified functional profiles. The “shift-and-persist” model (Chen & Miller, 2012) further suggests that adaptation to socioeconomic disadvantage involves specific psychological strategies, yet whether these strategies take culturally universal or culturally specific forms remains unclear. In high-stakes educational systems such as China's, standardized academic pressures may impose common developmental demands that attenuate socioeconomic differentiation in skill organization (Wang et al., 2025). In equity-oriented systems like Finland's, where student agency and intrinsic motivation are systematically fostered, socioeconomic background may be associated with more domain-differentiated pathways (Karseth et al., 2024). Understanding how socioeconomic background relates to social-emotional skill network organization across distinct cultural contexts is, therefore, essential for identifying context-sensitive intervention targets.

Theoretical basis

The Stage-Environment Fit theory supports the significance of age, positing that developmental outcomes depend on the alignment between an individual's psychological needs and the opportunities provided by the social context (Eccles et al., 1993). In childhood, SES is characterized by intrinsic curiosity and exploratory behaviors. However, adolescence brings increased academic competition, complex social hierarchies, and identity formation demands that trigger systemic reorganization (Cherewick et al., 2021), shifting from exploratory configurations toward resilience-focused and goal-directed patterns. Empirical research documents an “adolescent dip” in SES scores among adolescents compared to children (Huo & Ning, 2025b; OECD, 2021). However, a systems perspective suggests that mean-level variability may mask internal structural evolution. As individuals mature, interconnections between specific SES components become more stable and integrated (Taylor et al., 2015; Yurgelun-Todd, 2007), providing the foundation for advanced self-regulation and social cognition (Crone et al., 2020).

Despite advancements, critical gaps remain. First, existing research relies on linear models treating subskills as independent variables and focuses on mean-level differences without exploring structural maturation during development. Second, broad cross-cultural categorizations may obscure how specific cultural mandates and developmental stage-specific factors link to distinct functional architectures. While score disparities across socioeconomic and gender groups are documented, the degree to which these factors associate with network reorganization across cultural contexts and developmental stages remains underexplored.

The present study

This research aims to address the following research questions:

RQ1: What are the differences in the topographical organization and hub structure of SES between students in Jinan (China) and Helsinki (Finland)?

RQ2: How do SES network structures differ and reorganize between children (age 10) and students in Adolescents (age 15) across these two cultural contexts?

RQ3: How are gender differences reflected in the topographical configuration and global strength of SES networks within the Chinese and Finnish samples?

RQ4: How is socioeconomic status (SES) associated with the topographical configuration and global strength of SES networks across the two national contexts?

Methods

Participants and setting

This study is a secondary analysis of deidentified, publicly available data from the 2023 OECD Survey on Social and Emotional Skills (SSES). The original data collection process obtained ethical approval from the OECD and relevant local authorities, ensuring informed consent from all participants. We selected Jinan (China) and Helsinki (Finland) as our comparative sites for several reasons. First, these two cities represent contrasting cultural orientations: China, with its Confucian heritage, exemplifies a collectivist tradition where academic achievement is closely tied to family obligations and social harmony (Tao & Hong, 2014; Yang et al., 2024), while Finland represents the Nordic individualistic model emphasizing student agency, autonomy, and egalitarian education (OECD, 2021). Second, both cities participate in the SSES 2023, providing comparable data with robust psychometric properties across both contexts. Third, these urban educational settings represent the dominant mode of schooling in their respective countries, making them suitable case studies for cross-cultural comparison.

The Chinese sample (Jinan, $n = 6737$) included two age cohorts: 3454 10-year-old students ($M_{\text{age}} = 10.74$, $SD = 0.28$; 48.8% female; $M_{\text{SESs}} = -0.11$, $SD = 0.58$) and 3283 15-year-old students ($M_{\text{age}} = 15.70$, $SD = 0.28$; 47.7% female; $M_{\text{SESs}} = -0.14$, $SD = 0.58$). Similarly, the Finnish sample (Helsinki, $n = 5341$) was comprised of 2889 10-year-old students ($M_{\text{age}} = 10.72$, $SD = 0.30$; 48.9% female; $M_{\text{SESs}} = 0.47$, $SD = 0.61$) and 2452 15-year-old students ($M_{\text{age}} = 15.69$, $SD = 0.29$; 51.0% female; $M_{\text{SESs}} = 0.59$, $SD = 0.61$).

Measures

Social-emotional skill

Social-emotional skill was measured across five overarching domains (Task Performance, Emotional Regulation, Engaging with Others, Collaboration, Open-Mindedness). Each competency was evaluated through 6–8 items utilizing a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly agree). Rigorous measurement invariance testing confirmed cross-cultural and longitudinal validity (OECD, 2021).

Sociodemographic variables

Age was treated as a cohort-based categorical variable (1 = 10-year-olds, 2 = 15-year-olds). Gender was derived from the student questionnaire (1 = female, 2 = male). Socioeconomic status (SESs) refers to the relative social and economic position of a student's family, reflecting their access to material and cultural resources. In the SSES

2023, SESs was operationalized through the Index of Economic, Social, and Cultural Status (ESCS). This composite index is derived from 14 specific indicators, including parental education level, highest parental occupational status, and home possessions (OECD, 2025). In our study, High-SESs and Low-SESs were defined as the top and bottom 25% of the ESCS distribution within each city.

Data analyses

All statistical procedures were performed using R (Version 4.3.2) with the following core packages: *bootnet* for network estimation and stability (Epskamp et al., 2018), *qgraph* for high-dimensional visualization (Epskamp et al., 2012), and *NetworkComparisonTest* for testing structural invariance across groups (van Borkulo et al., 2023). To account for the cluster effect introduced by the nested data structure, we utilized sampling weights and robust estimation protocols to enhance the representativeness of the results.

Preliminary analysis

Means and standard deviations among the 15 SES facet-level skills were computed for both national samples and age cohorts. Furthermore, we conducted a series of independent-samples t-tests to evaluate significant differences in SES levels across cultural backgrounds (China vs. Finland), age groups (10-year-olds vs. 15-year-olds), and gender.

Network analysis

To investigate the complex interdependencies among social-emotional skills, we employed Gaussian Graphical Models (GGM). In these models, nodes represent the 15 SES facet-level skills, and edges denote partial correlation coefficients between nodes while controlling for all other variables in the system.

Network estimation and visualization

The network was estimated using the Least Absolute Shrinkage and Selection Operator (LASSO) regularization combined with the Extended Bayesian Information Criterion (EBIC) to obtain a parsimonious and stable structure. This technique effectively sets trivial edges to zero, minimizing the inclusion of false-positive connections. The tuning parameter (r) was set to 0.5 to balance the sensitivity and specificity of edge detection. Network visualization was performed using the Fruchterman-Reingold algorithm, where more central and strongly connected nodes are positioned toward the center of the graph.

Network evaluation

Node importance within the SES networks was assessed using Expected Influence (EI). Standardized z-scores of EI were calculated to identify central hubs that potentially activate or amplify the values of connected nodes across the system.

Network accuracy and stability

To ensure the robustness and reliability of the estimated networks, we implemented a comprehensive bootstrapping framework (Epskamp et al., 2018). First, a non-parametric

Table 1. Descriptive statistics for 15 social–emotional facet-level skills

SES domain	Social–emotional facet-level skills	Code name	10-year-old in China	15-year-old in China	10-year-old in Finland	15-year-old in Finland
Engaging with others	Sociability	SOC	588.17 (104.35)	545.59 (88.83)	564.75 (86.34)	547.13 (104.64)
	Assertiveness	ASS	592.71 (113.19)	527.64 (84.87)	499.15 (74.50)	499.70 (97.73)
	Energy	ENE	592.50 (121.13)	511.92 (91.31)	572.93 (109.20)	512.34 (92.38)
Open-mindedness	Tolerance	TOL	597.65 (128.99)	582.67 (95.98)	571.09 (82.33)	588.86 (90.13)
	Creativity	CRE	604.17 (127.67)	552.70 (102.50)	590.84 (103.24)	561.14 (97.06)
	Curiosity	CUR	627.00 (131.25)	589.35 (100.75)	573.18 (93.45)	563.42 (89.44)
Emotional regulation	Stress resistance	STR	560.73 (104.15)	514.69 (86.25)	526.51 (81.32)	507.24 (101.75)
	Optimism	OPT	600.64 (112.68)	552.13 (88.18)	586.33 (95.83)	545.67 (99.33)
	Emotional control	EMO	599.43 (127.48)	533.05 (97.47)	551.49 (89.12)	538.51 (96.64)
Collaboration	Trust	TRU	636.05 (150.30)	561.30 (108.69)	582.17 (96.34)	526.12 (93.69)
	Empathy	EMP	632.02 (125.04)	625.40 (108.19)	598.63 (101.46)	602.92 (104.62)
Task performance	Motivation	MOT	649.32 (117.73)	567.36 (89.66)	607.50 (98.94)	554.59 (94.28)
	Persistence	PER	663.33 (123.77)	581.22 (94.78)	611.24 (103.55)	568.08 (98.99)
	Responsibility	RES	668.30 (129.24)	598.63 (98.07)	600.07 (88.67)	587.93 (93.45)
	Self-control	SEL	634.10 (168.50)	573.22 (110.20)	548.32 (96.21)	535.62 (91.82)

bootstrap (1000 iterations) was conducted to estimate 95% confidence intervals (CIs) for edge weights; narrower CIs reflect higher precision and reliability in edge estimation. Second, a case-dropping bootstrap (1000 iterations) was performed to assess the stability of the centrality rankings. Stability was quantified using the Centrality Stability (CS) coefficient, with a threshold of $CS > 0.7$ required to ensure that centrality rankings remained consistent even after dropping a significant proportion of the sample.

Network comparison

To rigorously compare SES structures across cultures, age cohorts, and SES levels, we employed the Network Comparison Test (NCT) with 1000 permutations. The NCT evaluates three key aspects: (1) Network structure invariance, which tests whether the overall pattern of connections differs between groups; (2) Global strength invariance, which examines the difference in total absolute connectivity; and (3) Specific edge-weight invariance, which identifies individual connections that significantly differ across networks.

Results

Preliminary results

Descriptive statistics for the 15 social-emotional sub-competencies across the four groups are presented in Table 1. Chinese 10-year-old students exhibited the highest levels across nearly all competencies, particularly in Task Performance (Responsibility: 668.30; Persistence: 663.33) and Collaboration (Trust: 636.05; Empathy: 632.02). A pronounced age-related decline was observed in the Chinese sample. By age 15, Chinese students showed significantly lower scores in all 15 sub-competencies, with the most substantial decreases in Engaging with Others (Energy: 592.50 to 511.92; Assertiveness: 592.71 to 527.64). In contrast, Finnish cohorts demonstrated more

stable developmental trajectories, showing slight improvements in Open-Mindedness (Tolerance: 571.09 to 588.86) and Collaboration (Empathy: 598.63 to 602.92).

Cultural disparities were statistically significant for 14 of the 15 sub-skills ($p < 0.001$), with only Creativity showing no significant difference. Age effects showed significant decline in 13 competencies ($p < 0.001$), while Tolerance and Empathy remained stable. Gender differences were prevalent ($p < 0.01$), though Persistence did not vary significantly ($p = 0.06$).

Differences in topographical organization and hub structure between cultures (RQ1)

The regularized partial correlation networks for Chinese and Finnish students are visualized in Figure 1. The Chinese SES network exhibited high connectivity and integration, retaining 92 out of 105 possible edges with a sparsity of 0.124, suggesting a tightly coupled system. The Finnish SES network was relatively more sparse, retaining 86 edges with a sparsity of 0.181, indicating more differentiated organization.

Both networks exhibited robust skill clusters. The Task Performance cluster (MOT-PER-RES) showed strong connections, particularly the Motivation-Persistence link (Finland: $r = 0.476$; China: $r = 0.341$). The Open-mindedness cluster (CRE-CUR) showed tight coupling (Finland: $r = 0.313$; China: $r = 0.337$). An Emotional Regulation cluster (STR-EMO-OPT) was observed in both groups.

The Chinese network displayed unique configurations: stronger Emotional Control-Energy association ($r = 0.212$ vs. 0.109 in Finland), stronger Persistence-Responsibility connection ($r = 0.276$ vs. 0.200), and stronger Energy-Sociability link ($r = 0.245$ vs. 0.191). The Finnish network showed stronger Motivation-Persistence bond ($r = 0.476$), stronger Tolerance-Empathy association ($r = 0.272$ vs. 0.179), and stronger Sociability-Assertiveness link ($r = 0.274$).

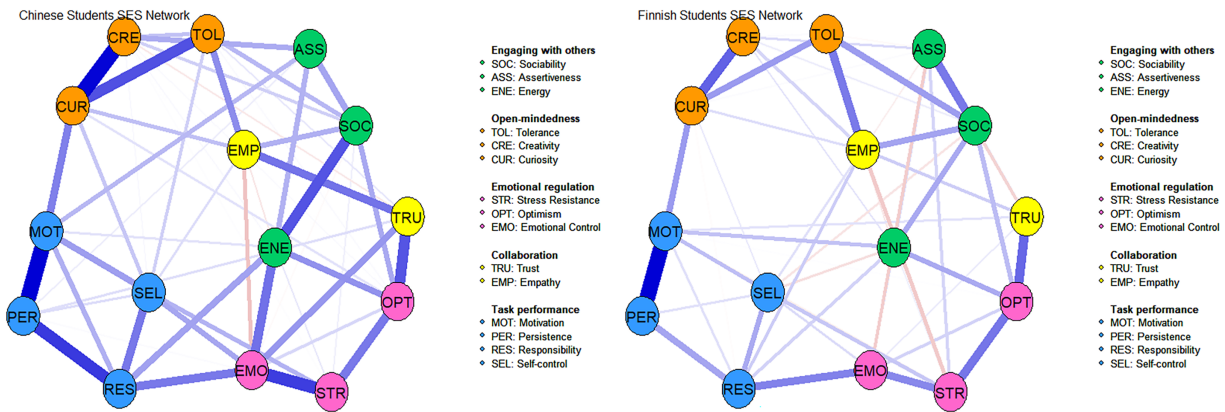


Figure 1. Chinese (left) and Finnish (right) students SES network

Developmental reorganization and hub transition across childhood and adolescence (RQ2)

As shown in Figure 2, at age 10, the motivational cores of Chinese and Finnish students exhibited distinct profiles. In the Chinese 10-year-old sample, Curiosity (CUR) emerged as the absolute systemic core, indicating that SES development in late childhood is heavily anchored in intrinsic cognitive exploration. Furthermore, the high centrality of Self-control (SEL) and Tolerance (TOL) reflected a strong emphasis on rule awareness and social harmony within the East Asian context. In contrast, the Finnish 10-year-old network demonstrated a more balanced dual-drive configuration, where Motivation (MOT), Optimism (OPT), and Sociability (SOC) collectively served as the primary hubs. A notable cross-cultural commonality was the peripheral role of Assertiveness (ASS), which exhibited extremely low influence in both regions, suggesting that dominant social behaviors are not yet integrated as functional hubs in late childhood.

By age 15, both national networks underwent dramatic structural reconfiguration. In China, the network core transitioned from curiosity-driven to resilience-driven, with Optimism (OPT) and Persistence (PER) achieving peak systemic influence. This hub formation represents a psychological adaptation mechanism necessitated by the high academic pressures students face in secondary education. Meanwhile, the Finnish adolescent network featured a massive surge in the influence of Sociability (SOC), which became the single most powerful lever for social-emotional growth, far exceeding its role in the Chinese cohort. A critical structural vulnerability was identified in the Chinese 15-year-old sample regarding Empathy (EMP); unlike the integrated role of empathy in Finnish students, its Expected Influence in the Chinese adolescent network collapsed to an extreme negative level, signaling a severe functional isolation or decoupling of interpersonal sensitivity from other core competencies.

Gender differences in network topographical configuration and global strength (RQ3)

Gender-based analysis revealed context-specific configurations of the SES system for male and female students (as shown in Figure 3). For male students, both the Chinese and Finnish networks emphasized the Emotional

Regulation domain as a functional axis. Specifically, Stress Resistance (STR) and Emotional Control (EMO) emerged as the primary hubs for boys across both samples. In the Finnish male cohort, Stress Resistance demonstrated a slightly more pronounced relative influence compared to Chinese males, while the Chinese male network showed a more centralized link between internal regulation and behavioral Persistence. These patterns suggest that managing internal distress serves as a shared systemic driver for boys globally, albeit with different functional targets.

For female students, the centrality patterns diverged from their male peers by prioritizing prosocial and conscientious nodes. In both national samples, female students displayed significantly higher Expected Influence for Collaboration and Task Performance nodes, such as Empathy (EMP) and Responsibility (RES). In the Chinese female sample, these competencies were more tightly integrated with the Curiosity node, whereas Finnish females showed a more robust link between Collaboration and Sociability. These results indicate that for girls, the engine of social-emotional development is characterized by a higher degree of integration between interpersonal sensitivity and goal-oriented behaviors, reflecting shared gendered developmental pathways across these distinct cultures.

The moderating role of socioeconomic status (SESs) on network organization (RQ4)

Socioeconomic background was associated with distinct centrality patterns in both cultural contexts (as shown in Figure 4). In the Chinese sample, low-SESs students' networks were more strongly anchored by Emotional Regulation and Task Performance facets, specifically Optimism, Motivation and Persistence. High-SESs students showed higher centrality for Self-Control and Energy. Open-Mindedness facets displayed minimal SESs-associated variation. In the Finnish sample, a different descriptive pattern emerged. High-SESs students showed higher centrality for Responsibility, Persistence, Tolerance, and Emotional Control, whereas low-SESs students demonstrated higher centrality for Open-Mindedness facets such as Curiosity and Creativity. Engaging with Others facets and Trust remained stable across SES groups. Cross-cultural comparison revealed that SESs-related centrality variation was concentrated in Emotional Regulation and Engaging with Others in China, but was

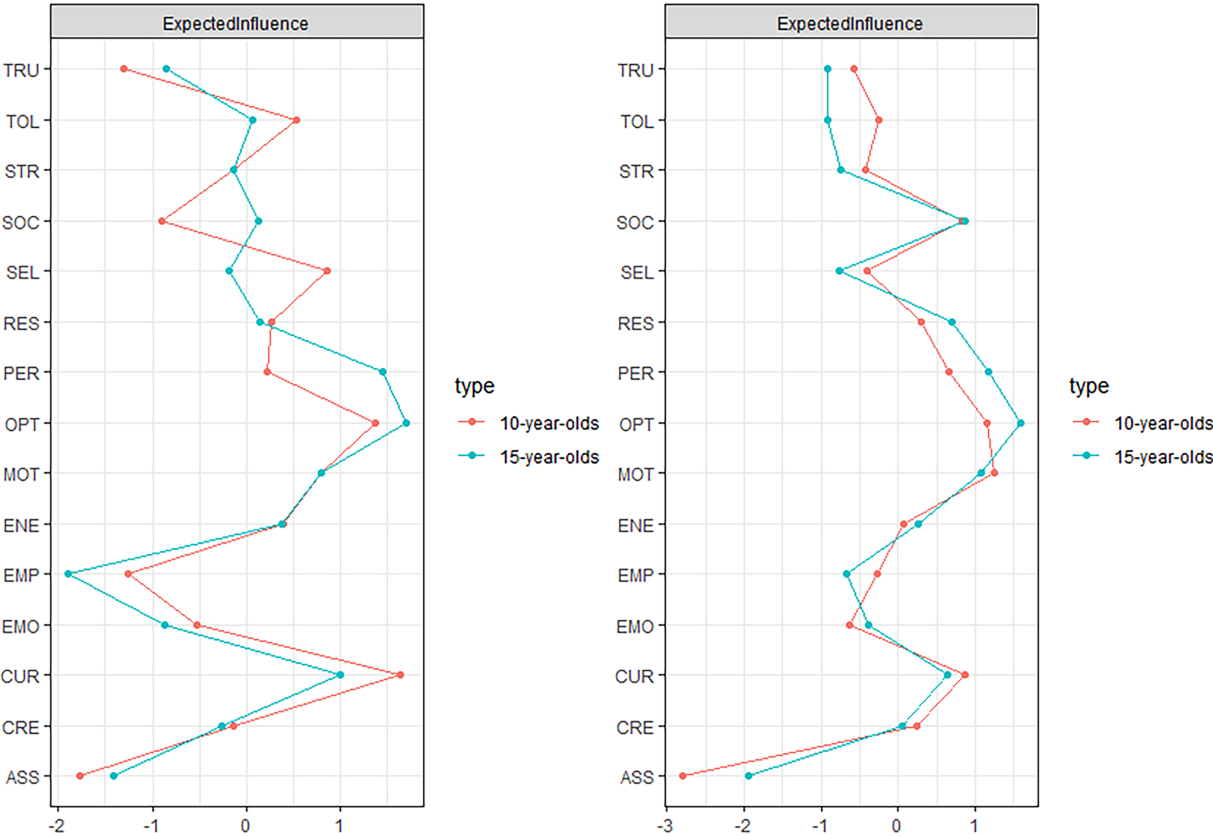


Figure 2. Standardized estimates of expected influence (EI) for the skill facets among China (left) and Finland (right)

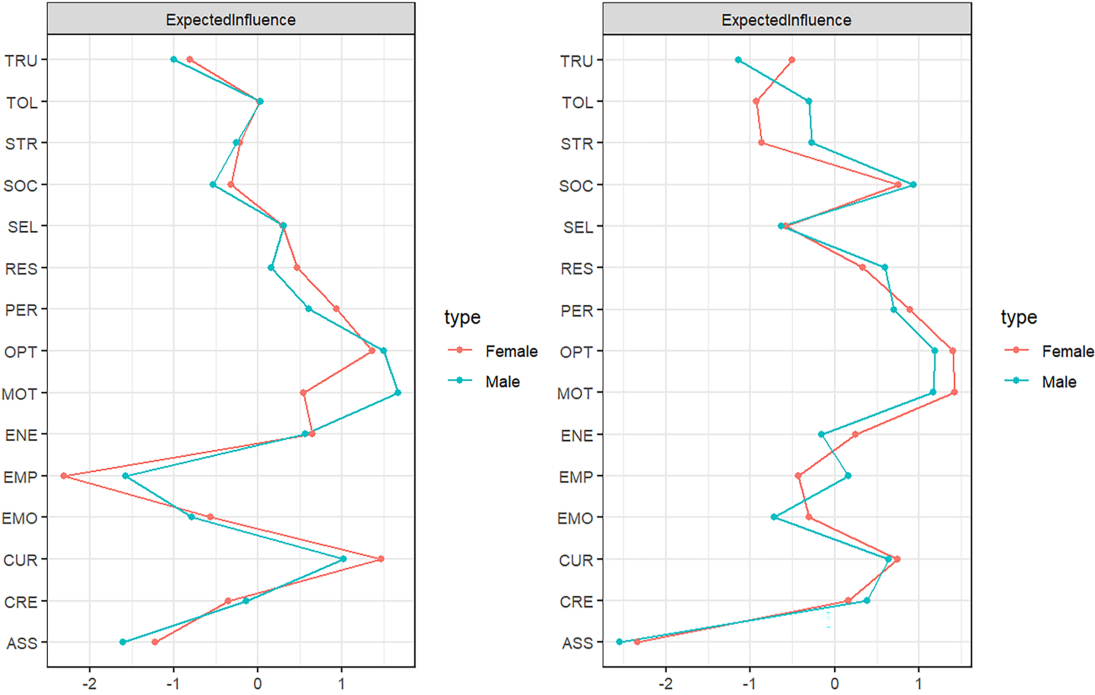


Figure 3. Standardized estimates of expected influence (EI) for the skill facets cross gender, China (left) and Finland (right)

distributed across Open-Mindedness, Task Performance, and Emotional Regulation in Finland. Low-SESs advantages diverged accordingly. Chinese low-SESs students showed relative strengths in emotion regulation, while their Finnish counterparts showed strengths in cognitive exploration.

Network accuracy and stability

Bootstrapping confirmed narrow 95% confidence intervals for edge weights. The Centrality Stability coefficient for Expected Influence was $CS = 0.75$ for both samples, exceeding the threshold of $CS > 0.7$ (Epskamp et al., 2018).

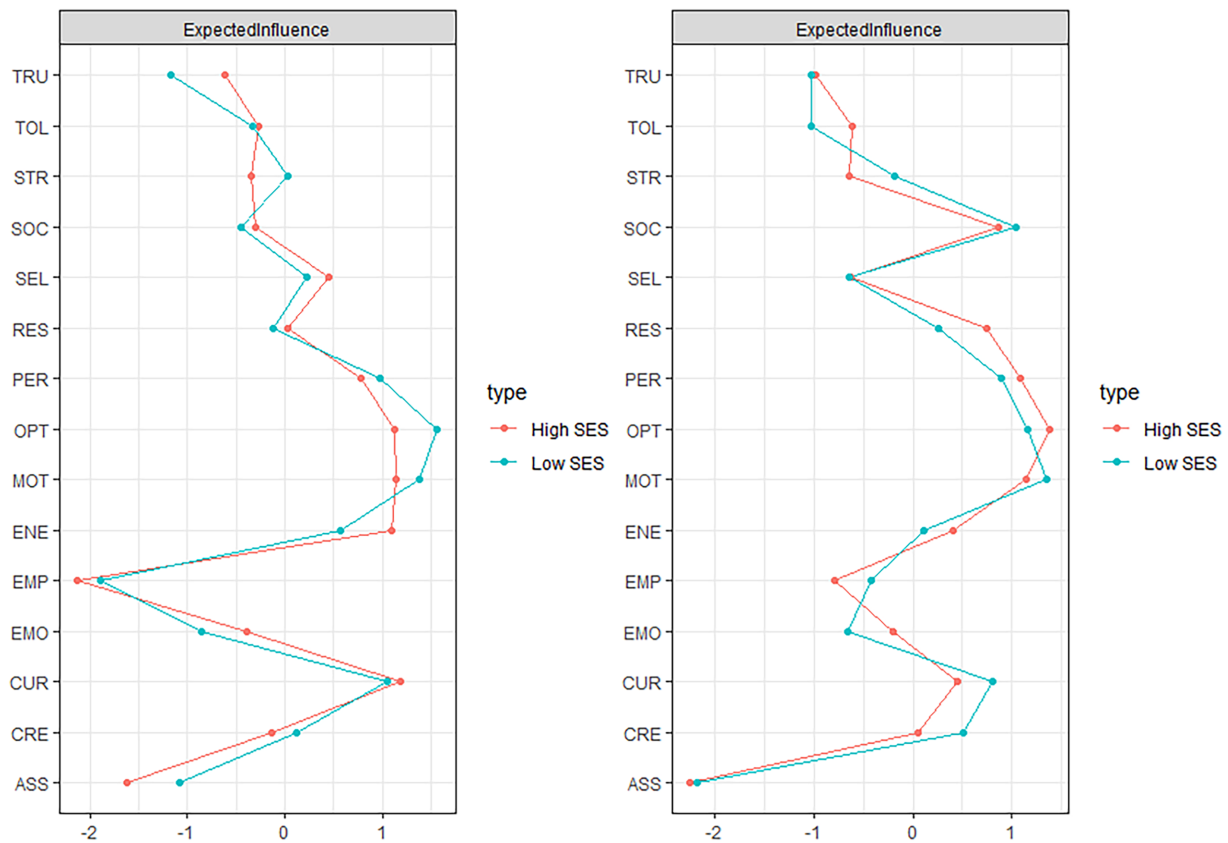


Figure 4. Standardized estimates of expected influence (EI) for the skill facets based SESs, China (left) and Finland (right)

Network comparison

The NCT with 1000 permutations revealed: (1) significant network structure differences between Chinese and Finnish samples ($M = 0.135$, $p < 0.001$); (2) significant age-related reconfigurations in both samples (China: $M = 0.145$, $p < 0.001$, global strength from 7.79 to 9.31; Finland: $M = 0.178$, $p < 0.001$, global strength from 8.07 to 9.36); (3) gender differences only in the Finnish sample ($M = 0.169$, $p < 0.001$); and (4) SESs differences only in the Finnish sample ($S = 1.674$, $p < 0.001$).

Discussion

This study conducted a cross-cultural network analysis of SES among children and adolescents in Finland and China using SSES 2023 data. While SES networks in both contexts exhibited high overall integration, specific organizational patterns showed clear cultural variations shaped by local values and educational priorities.

Cultural divergence in social-emotional skill interconnections

The NCT confirmed that the overall organization of SES is notably different between students in Jinan and Helsinki. Specifically, a prominent difference lies in the drive mechanism for task-oriented behavior. In the Finnish sample, the connection between Achievement Motivation (MOT) and Persistence (PER) was exceptionally robust ($r = 0.476$), stronger than in the Chinese sample ($r = 0.341$). This finding is consistent with previous cross-cultural research indicating that Finnish students tend to report higher levels of achievement motivation than

Chinese students (Hernesniemi et al., 2020). This tight coupling is consistent with the values of individualistic cultures, where achievement is often driven by internal desires and self-interest (Wang et al., 2020). In the Nordic educational framework, which emphasizes student agency and autonomous learning, persistence is functionally integrated with intrinsic motivation (Karseth et al., 2024). For Finnish students, staying with a task appears to be a direct behavioral manifestation of their internal desire to achieve, which aligns with previous research (Hotulainen et al., 2020; Tuominen et al., 2020), suggesting that individualistic achievement is often fueled by personal satisfaction and self-actualization.

In contrast, the Chinese SES network relies more heavily on an emotional management strategy to sustain vitality. The association between Emotional Control (EMO) and Energy (ENE) was notably stronger in Jinan ($r = 0.212$) than in Helsinki ($r = 0.109$). This finding supports three key assertions unique to the Chinese context. First, in China's collectivist and high-pressure academic environment, maintaining engagement and vitality requires rigorous self-regulation rather than motivation alone. Empirical research confirms that emotion regulation serves as a critical psychological resource for sustaining academic effort under competitive pressures (Tang & He, 2022). Second, emotion regulation is strongly linked to learning engagement and vitality among Chinese students. Studies demonstrate that self-control and emotion regulation strategies directly predict learning engagement and psychological capital among Chinese learners (Yang et al., 2024), while self-regulation through resilience mediates

the relationship between emotional management and sustained learning investment (Zhi & Derakhshan, 2024; Ge, 2025). Third, emotion regulation is particularly critical in Chinese cultural contexts characterized by high-stakes examination culture, where students must actively manage emotional states to suppress fatigue and anxiety, thereby maintaining the energy required to meet external expectations (Fang et al., 2023; Fu, 2024).

Furthermore, the interpersonal domain exhibited distinct cultural patterns. The Finnish network showed a stronger link between Tolerance (TOL) and Empathy (EMP) ($r = 0.272$) compared to the Chinese sample ($r = 0.179$). In an individualistic society like Finland, where diversity and egalitarianism are core values, understanding others (empathy) is more directly translated into accepting differences (tolerance). This observation aligns with the results of meta-analyses (Imuta et al., 2016; Qiu et al., 2024), indicating that empathy can enhance students' prosocial abilities and foster inclusive behavior. Conversely, the Chinese network demonstrated a unique integration of persistence and responsibility. The connection between Persistence (PER) and Responsibility (RES) was clearly more robust in China. This finding supports three key assertions unique to the Chinese context. First, in Confucian-influenced societies, persistence is tightly coupled with responsibility as a moral imperative. Chen's (2023) dual-mode achievement goal framework distinguishes "obligation-oriented" from "improvement-oriented" effort beliefs, demonstrating that in Chinese cultural contexts, studying hard and achieving good grades are viewed as role obligations and learning virtues. Second, for Chinese students, persistence is frequently experienced as a moral duty to family and school rather than a personal choice. Research shows that obligation-oriented effort beliefs are grounded in filial piety and family obligation, where academic perseverance is understood as honoring parental expectations and repaying family investment (Fwu et al., 2018; Guo et al., 2022). Third, the moral dimension is more centrally integrated into the achievement system in Chinese educational contexts. Qualitative studies confirm that perseverance and responsibility are simultaneously regarded as core qualities driving academic success in Chinese students—achieving well is not only an achievement outcome but also a fulfillment of family expectations (Chen, 2023; Liu et al., 2022).

Developmental evolution across cultures

The age-related comparisons provided by the NCT show that SES is a dynamic system that reorganizes significantly as adolescents mature. While individual skill levels often fluctuate during this period, the overall network structure becomes more integrated and stable.

First, a universal finding across both the Jinan and Helsinki samples was the clear increase in global network strength from age 10 to 15. In line with prior research, our results suggest that as students move into mid-adolescence, their social-emotional skills become more tightly coupled and mutually reinforcing (Huo & Ning, 2025b). This developmental consolidation aligns with neurobiological evidence (Yurgelun-Todd, 2007) from multiple

brain development reviews, indicating that from childhood to adolescence, the prefrontal cortex and emotion-related networks undergo structural and functional reorganization through processes of "network strengthening and differentiation". These neural changes support more advanced cognitive control, emotional regulation, and social cognition during this period.

Second, the specific nodes that drive the SES network underwent a distinct transition in the Chinese sample. At age 10, the Chinese network was primarily driven by curiosity, suggesting that late childhood development is centered on exploration and intrinsic interest. However, by age 15, the focus shifted to a resilience-based core dominated by optimism and persistence. This transition likely reflects the impact of the high-pressure academic environment in China, particularly as students approach the Senior High School Entrance Examination (Zhongkao). As academic demands intensify, internal exploration (curiosity) is replaced by the functional need for goal-directed effort and a positive mindset. This observation aligns with the "Control-Value Theory" (Pekrun et al., 2007), which posits that achievement-oriented environments force a realignment of emotional resources to sustain long-term performance. Simultaneously, the developmental trajectory in the Finnish sample followed a different path, characterized by a significant surge in the influence of sociability at age 15. In Helsinki, sociability became the most central driver for adolescent SES, indicating that social engagement is a key lever for overall development in the Nordic context. This finding reflects the Finnish educational model's emphasis on student agency and social integration (OECD, 2021). Unlike the performance-driven shift observed in Jinan, Finnish adolescents appear to consolidate their SES through social interactions and interpersonal engagement, which reinforces the cultural priority placed on egalitarian participation and collective well-being.

Finally, a notable developmental divergence was the clear decoupling of empathy in the Chinese 15-year-old network. While empathy remained an integrated and stable component of the Finnish network, its Expected Influence in the Chinese adolescent cohort shifted to a low level ($z \approx -2.0$). This structural "crisis point" suggests that under the pressure of intense academic competition, interpersonal sensitivity may become isolated from other core competencies in Chinese adolescents. This finding extends previous observations of the "adolescent dip" in SES (Huo & Ning, 2025a), and reveals a deeper structural risk: empathy becomes functionally decoupled from the network, losing its capacity to interact with and reinforce other social-emotional skills. This isolation suggests that achievement-oriented environments may inadvertently marginalize the relational aspects of development in favor of individual resilience.

Gendered patterns of SES organization

Gender serves as a lens through which social-emotional development is filtered, reflecting the internalized social expectations of different culture. The results indicate that while some gendered patterns of SES organization are universal across Chinese and Finnish contexts, others are

uniquely shaped by the local cultural and educational landscape.

In the context of male students, both samples emphasize the Emotional Regulation domain. Stress Resistance and Emotional Control serve as primary hub nodes for boys in both regions. This is consistent with Guo et al. (2023), who identified regulatory hubs as critical bridge nodes for resilience among Chinese males. Managing internal distress thus acts as a functional “shield” against environmental pressures, aligning with traditional masculine norms that prioritize emotional stoicism to sustain performance.

Meanwhile, for female students, SES organization features high integration between communal and agentic skills. Female networks in both cities showed robust links between the Collaboration and Task Performance domains. This aligns with Van der Graaff et al. (2018), who observed that for girls, prosocial behavior and empathy-related traits are mutually reinforcing throughout adolescence. In our study, interpersonal sensitivity and social responsibility are functionally tied to goal pursuit. This suggests a developmental path where pro-sociality and achievement support one another, consistent with the integration of relational care and self-directed competence.

Furthermore, a notable cross-cultural distinction emerged regarding the extent of these differences. In the Chinese sample, NCT results showed that overall network structure and global strength did not differ between boys and girls ($M = 0.086, p = 0.366$). This suggests a uniform social-emotional profile among Chinese adolescents, likely due to shared academic pressures that override gender-specific paths. In contrast, the Finnish sample showed clear gender-based differences in structure ($M = 0.169, p < 0.001$) and global strength ($S = 0.909, p = 0.026$). This indicates that in the Finnish context, developmental paths for social engagement and performance are more structurally distinct and gender-specific.

Socioeconomic status as a moderator of SES networks

Socioeconomic background was associated with the functional organization of social-emotional skills in culturally specific ways, challenging a universal compensatory account. In the Chinese sample, low-SESs students' networks were anchored by Emotional Regulation and Task Performance. This pattern aligns with Conservation of Resources theory (Hobfoll, 1989), which posits that individuals facing resource constraints prioritize internal psychological capital as functional drivers. The minimal SESs-associated variation in Open-Mindedness further suggests that cognitive exploration operates relatively independently of economic background in China, perhaps reflecting the homogenizing influence of a standardized curriculum that exposes all students to common intellectual demands (Wang et al., 2025). The concentration of SESs-related centrality differences in Emotional Regulation and Engaging with Others implies that socioeconomic differentiation in this context primarily manifests in how students manage affect and social interaction, rather than in how they engage with cognitive tasks.

In Finland, a contrasting pattern emerged. Low-SESs students showed higher centrality in Curiosity and Creativity, whereas high-SESs students' networks emphasized Responsibility, Persistence, and Tolerance. This broader distribution of SESs-associated differences across domains is consistent with the Nordic educational model, which systematically fosters intrinsic motivation and exploratory learning across all socioeconomic levels (Karseth et al., 2024). The finding that low-SESs Finnish students leverage cognitive exploration as relatively central drivers may reflect the compensatory role of an equity-oriented system that provides universal access to intellectually stimulating environments.

Cross-culturally, these findings challenge the shift-and-persist model (Chen & Miller, 2012) as a universal framework for understanding socioeconomic adaptation. Rather than low-SES students uniformly adopting an optimism-persistence strategy, the facets that served as functional drivers varied by cultural context, Emotional Regulation in China and Open-Mindedness in Finland. The cross-contextual stability of Curiosity and Trust further indicates that certain functional roles within the social-emotional skill network are robust to socioeconomic influence, pointing toward universal candidate targets for intervention.

Theoretical and practical implications

This study provides important theoretical evidence that the defining characteristics of SES are culturally contingent, differing between individualistic and collectivist frameworks. By adopting a network approach, we have confirmed that individualism is associated with a system organized around self-agency and autonomous integration, while collectivism aligns skill organization with social governance and moral obligation. Furthermore, our finding that the specific functional drivers associated with socioeconomic background differed across cultural contexts contributes to resilience theory by demonstrating that the role of psychological resources in compensating for limited external capital is itself culturally mediated (Chen & Miller, 2012; Hobfoll, 1989). The cross-cultural comparison is essential because it reveals culturally specific phenomena that single-culture studies cannot capture. For instance, our findings show that empathy undergoes structural decoupling in Chinese 15-year-olds but remains stable in Finnish peers, highlighting a culturally specific vulnerability that warrants targeted intervention in Chinese educational contexts (Huo & Ning, 2025a). Regarding gender differences, our network analysis reveals distinct SES organizational patterns between males and females. In Chinese contexts, gender differences are minimal in network structure, suggesting uniform developmental pathways. However, in Finnish contexts, clear gender-based differences emerge, with males emphasizing Emotional Regulation and females showing integration between Collaboration and Task Performance (Van der Graaff et al., 2018). These findings necessitate gender-aware intervention strategies. Finnish educators should consider gender-specific approaches, while Chinese contexts may benefit from more universal

programs. Regarding SESs, the functional centrality profiles differed across cultural contexts rather than following a universal compensatory pattern. Low-SESs Chinese students' networks were anchored by Emotional Regulation and Task Performance facets, whereas low-SESs Finnish students showed higher centrality in Open-Mindedness facets. These findings underscore the need for culturally sensitive rather than uniformly applied SESs-tailored educational strategies.

This study also has practical implications that directly address our comparative findings. For Chinese educational contexts, the identified structural isolation of empathy among Chinese adolescents warrants programs that explicitly prioritize relational development in high-pressure academic environments. This suggests that schools should implement social-emotional programs that validate emotional experiences and ensure interpersonal sensitivity remains integrated during mid-adolescence. For Finnish educational contexts, the distinct gender-based network patterns indicate that gender-specific intervention approaches may be more appropriate than universal programs (Guo et al., 2023). For low-SESs populations, the specific intervention target should be aligned with context-specific functional drivers. In China, emotion-regulation training may be particularly beneficial for disadvantaged students, while in Finland, programs that build on cognitive exploration strengths could be more effective (Mrázek et al., 2018). High-SESs students in both contexts showed enhanced conscientiousness and open-mindedness clusters, indicating that creativity-fostering practices are particularly beneficial for affluent contexts (Castillo-Vergara et al., 2018; Wang et al., 2025).

Limitations and future directions

The conceptualization of SES remains highly complex, with numerous frameworks currently in use. While our study supports the validity of the SSES framework based on the Big Five taxonomy, future research is encouraged to integrate or compare multiple frameworks, such as the CASEL model (see <http://exploresel.gse.harvard.edu/>). Such comparisons would allow for a more nuanced understanding of social-emotional skills across different national contexts. Another limitation relates to sample representativeness. The present study draws on data from Jinan (China), and Helsinki (Finland), which serve as case studies for cross-cultural comparison. Jinan represents an urban educational context influenced by Confucian cultural traditions, while Helsinki reflects the Nordic educational model emphasizing student agency and equity. However, these cities are not nationally representative samples, and findings should be interpreted with caution when generalizing to entire countries. Future research should consider incorporating samples from multiple cities within each country to enhance the generalizability of cross-cultural findings. A further limitation is associated with the cross-sectional nature of the SSES 2023 database. This design prevents the establishment of definitive causal claims regarding the developmental reconfigurations observed between the 10- and 15-year-old cohorts. Moreover, this study did not account for intra-cultural diversity or potential confounding factors, such as

urban-rural disparities. These variables may also be linked to SES network structures, and their exclusion limits the scope of the findings regarding within-country variations.

Furthermore, this research relied on student self-reports, which may be susceptible to social desirability bias. Although previous research has demonstrated the cross-national reliability and validity of self-reported SES (Guo et al., 2023), self-reports may not fully capture actual behavioral tendencies in real-world environments. To enhance measurement validity, future studies should consider triangulating data sources by incorporating teacher or parent assessments.

Finally, while we identified several edges that strengthened or weakened across age groups, the theoretical explanations for these changes are not always straightforward. Although we have proposed possible mechanisms for specific skill connections, the reasons behind other age-related shifts remain unclear and may reflect contextual or cultural factors not captured by our models. Future research should prioritize tracking individual network maturation over time to further validate these findings.

Conclusion

This study analyzed SES networks among 12,078 students in Jinan (China) and Helsinki (Finland). Results show that SES is a dynamic and culturally contingent system with distinct organizational patterns across cultural contexts, developmental stages, gender, and socioeconomic status. Key findings include: (1) The Chinese network shows higher connectivity with the Emotional Regulation domain as the primary anchor, while the Finnish network exhibits a more differentiated structure with Engaging with Others as the central domain. (2) Network global strength increases from age 10 to 15 in both contexts, but hub nodes shift from curiosity to resilience in China and from curiosity to sociability in Finland. (3) The structural decoupling of empathy in Chinese 15-year-olds represents a critical developmental concern. (4) Low-SESs students' networks were anchored by Emotional Regulation and Task Performance facets in China, whereas low-SESs Finnish students showed higher centrality in Open-Mindedness facets. Theoretically, this research shifts focus from score-based comparisons to structural configurations of SES, identifying functional drivers within the system. Practically, findings highlight the need for culturally tailored interventions: Chinese contexts should prioritize empathy integration in adolescence, while SESs-related interventions should be culturally calibrated to context-specific patterns.

Acknowledgement: We extend our gratitude to the OECD and the SSES research team for providing access to the SSES 2023 dataset.

Funding Statement: The study received no funding.

Author Contributions: Shuai Zhang: Conducted the initial literature review, designed the research methodology, and performed the data analysis. Contributed to drafting the manuscript and preparing the final version for submission. Wenxi Wu: Collected and organized the data from the SSES 2023 database. Assisted in the data analysis

and interpretation of results. Participated in the drafting of the results and discussion sections. Jiheng Wu: Developed the theoretical framework for the study and provided guidance on the research methodology. Contributed to the writing of the introduction and literature review sections. Offered critical feedback on the manuscript drafts. Ge Chen: Responsible for the statistical analysis and ensured the accuracy of the data interpretation. Assisted in the preparation of figures and tables. Provided insights on the discussion of the study's implications. Rui Zhao: Supervising data collection/analysis, and coordinating manuscript revisions with Shuai Zhang. Binyan Xu: Overseeing the project. Contributed to the interpretation of results and the development of conclusions. Played a key role in refining the manuscript, focusing on the clarity and coherence of the arguments presented. Assisted in the submission process and corresponded with the journal during the review process. All authors reviewed and approved the final version of the manuscript.

Availability of Data and Materials: The data that support the findings of this study were derived from the public OECD SSES 2023 database (<https://www.oecd.org/en/data/datasets/SSES-Round-2-Database.html>) and are available from the corresponding author upon reasonable request.

Ethics Approval: This study is a secondary analysis of de-identified, publicly available data from the 2023 OECD Survey on Social and Emotional Skills (SSES). The original data collection process obtained ethical approval from the OECD and relevant local authorities, ensuring informed consent from all participants.

Conflicts of Interest: The authors declare no conflicts of interest.

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