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The relationships between perceived teacher autonomy support, academic self-efficacy and learning engagement among primary school students: A network analysis

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Abstract
Learning engagement is malleable to environmental change. An important learning environment created by teacher-student interactions is perceived teacher autonomy support, which may trigger learning engagement directly and/or indirectly by enhancing academic self-efficacy. In this study, we apply a network approach to explore the relationships between the specific facets of perceived teacher autonomy support, academic self-efficacy and learning engagement, and a sample consisting of 215 students in the fifth and sixth grades from a primary school in Changchun of China is used. Node centrality indicators and the accuracy and stability of the network are also calculated. The results reveal that there are no edges between the three facets of perceived teacher autonomy support and the three facets of learning engagement, and the shortest path connecting the two constructs is through academic ability self-efficacy. Furthermore, learning support, academic ability self-efficacy, and dedication have the top three strengths in the network, which indicates that the three facets are more closely related to other facets of the network.

Keywords Perceived teacher autonomy support · Academic self-efficacy · Learning engagement · Network analysis · Conditional independence

Introduction

Learning engagement, as an aspect of motivation for learning success, has recently received increasing attention in psychology and education (Ni & Wu, 2011). From the perspective of positive psychology, the promotion of learning engagement is beneficial

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to academic achievement, student satisfaction, professional maturity, and mental health (Ahlfeldt et al., 2005; Saeki & Quirk, 2015; Yoon et al., 2020). Although learning engagement has been studied across all grade levels (Aspland, 2009; Cahyadi et al., 2021; Lin, 2021), we focused on primary school as it is believed to be the source of disengagement from school, including boredom, passivity during lessons, and skipping school (Hornstra et al., 2013; Näkk & Timoštšuk, 2019). Learning engagement is defined as a positive and fulfilling state related to learning and includes three facets: vigour, dedication, and absorption (Schaufeli et al., 2002), which are presumed to be malleable to environmental change (Fredricks et al., 2004).

The learning environment created by teacher-student interactions has an important influence on learning engagement (Bronfenbrenner & Evans, 2000; Christenson et al., 2012; Reyes et al., 2012). Teacher autonomy support is an important component between teachers and students that contributes to the internalisation of students' external motivation. Perceived teacher autonomy support is defined as students' perceptions about teachers' support and encouragement for their autonomy decisions and choice, and it has three facets: learning support, emotional support, and ability support (Babad, 1990; Ryan & Solky, 1996). Learning support refers to students' beliefs that teachers care about their learning and can help them solve problems in the learning process; emotional support reflects students' perceptions about their teachers' acceptance, trust, warmth, and so forth; and ability support is characterized by encouraging students to actively participate in classroom and extracurricular activities (Mageau & Vallerand, 2003; OuYang, 2005).

A number of empirical studies have found that perceived teacher autonomy support is positively associated with learning engagement (Duan et al., 2019; Fredricks et al., 2004; Sawka et al., 2002) and helps students reduce distractions and deviant behaviors (Jin & Wang, 2019; Strati et al, 2017). Students will increase their learning engagement when they perceive expectations, positive attitudes, or autonomy support from their teachers. Fu (2018) reported a positive correlation between each facet of perceived teacher autonomy support and learning engagement. Duan et al. (2019) showed that perceived teacher autonomy support significantly predicted learning engagement and its various facets. However, the relationships between perceived teacher autonomy support's specific facets and learning engagement's specific facets are understudied.

According to self-determination theory, perceived teacher autonomy support can enhance students' academic self-efficacy (Deci & Ryan, 2000; Scott & Walczak, 2009). Academic self-efficacy refers to students' perceptions or beliefs about their capabilities to achieve academic success, and mainly includes two facets: academic ability self-efficacy and academic behavior self-efficacy (Bandura, 1999; Fredricks et al., 2004; Kim et al., 2018). Perceived teacher autonomy support and academic self-efficacy were found to be positively correlated in different groups of participants (Chen, 2015; Zhang et al., 2019). Moreover, academic self-efficacy was found to be positively correlated with learning engagement, and it can mediate the effect of an independent variable, such as socio economic status and student motivation, on academic performance (Schaufeli et al., 2002; Wu et al., 2020).

The above studies all shed some light on the relationships between perceived teacher autonomy support, academic self-efficacy and learning engagement; however, the relationships between the specific facets of the three constructs have not been adequately investigated. Understanding the relationships between the facets of different constructs is essential, because each facet of a construct might relate differently to the other construct or its facets. Therefore, the relationships can be incorrectly characterized and lack specificity

when we look at a construct as a whole rather than investigating its facets (Gonzalez & MacKinnon, 2018).

Correlation analysis cannot reveal the direct or indirect connections between variables. Fortunately, network analysis can be applied to explore the conditional independence/dependence relationship between two variables and may be interpreted as indicative of potential causal pathways (Epskamp et al., 2018b). Network analysis is a new theoretical and statistical approach in psychology, first proposed by Borsboom (2008). It has been successfully applied in the fields of psychopathology and personality, such as PTSD (Zweerings et al., 2018), suicide (Rath et al., 2019), the Big Five personality traits (Papageorgiou et al., 2019), and coping and resilience (Hallen et al., 2020). This is a useful tool for exploratory analysis that allows researchers to estimate (and visualize) the relationships between multiple variables (Borsboom, 2008; Cramer et al., 2010; Wagenmakers et al., 2011). In the framework of a psychological network, the relationships between nodes (i.e., variables) are examined and the multivariate dependence between variables can be depicted graphically (Epskamp & Fried, 2018).

Network analysis provides a means to examine the dependence of the various facets between perceived teacher autonomy support, academic self-efficacy, and learning engagement, by determining whether these facets are distinct and only minimally correlated with each other, or if they emerge as part of a coherent network. If these facets form a coherent network structure, the importance of each facet in the network can be further assessed by centrality indices (Schmittmann et al., 2013). For centrality analysis, commonly used indices include strength, closeness and betweenness. Recent studies have shown that strength has greater stability and reliability than closeness and betweenness in psychological networks (Costantini et al., 2019; Epskamp et al., 2018a). In addition, nodes in a network that are highly related to other nodes have been described as bridge nodes, which are used to describe the network structures between different constructions (Greene et al., 2020; Jones et al., 2021).

The present study investigated the network between perceived teacher autonomy support, academic self-efficacy, and learning engagement among primary school students in the fifth and sixth grades. We estimated a network that included eight nodes and gave the centrality index for each node. We also identified bridge nodes in the network using a new computational method proposed by Jones et al. (2021) and tested the accuracy and stability of the network structure. Network analysis provides a new perspective for exploring the cause-effect relationships between specific facets of the same or different constructs. Unlike structural equation modeling, network analysis does not rely on theoretical assumptions about the relationships between variables. Furthermore, network analysis can reveal core variables from a network perspective, providing guidance for further research and practice.

Method

Participants

Using a convenience sampling method, a total of 251 students were recruited from the fifth and sixth grades of a primary school in Changchun of China. After excluding 36 participants who did not complete all the items or responded to the items following obvious rules (e.g., selection of answer 1 for all items), the final sample consisted of 215 participants,

with an effective response rate of 85.66%. Among the participants, there were 112 boys and 103 girls, with 95 students in grade 5 and 120 students in grade 6.

Procedure

The survey was conducted in classrooms in early December 2020 when the students were in the traditional classroom learning environment. All students participated voluntarily, and consent was obtained from the school director, the student's classroom teacher and the students before administering the questionnaire. The questionnaire was written in Chinese and administered using a uniform guideline. The participants were asked to complete all items on the questionnaire within 30 min. It was emphasized that their responses to the items were not right or wrong and should be answered according to the actual situation. Questionnaires were collected upon completion. The participants did not receive any incentive or reward for completing the questionnaire. The statistical software SPSS 26.0 and R 4.0.2 were used for data analysis.

Assessment

Perceived teacher autonomy support

The Student Perceived Teacher Support Behavior Questionnaire was used to assess perceived teacher autonomy support (Babad, 1990), and the Chinese version of this scale showed good reliability and validity (OuYang, 2005). It has 19 items: 9 items for learning support (e.g., "When I answer questions about my mistakes, my teachers often explain to me the reason for my mistakes and how to correct them."); 5 items for emotional support (e.g., "The teacher has always been very gentle to me."); and 5 items for ability support (e.g., "The teacher often recommends me to participate in various activities or competitions."). Each item was presented on a 6-point Likert-type scale, ranging from 1 (strongly disagree) to 6 (strongly agree). Higher scores on one dimension indicate that students perceive stronger learning support, emotional support, or ability support from their teachers. For the current sample, the internal consistency of Cronbach's alpha of the total score was 0.84, and internal consistency characterized the subscales of learning support ($\alpha = 0.72$), emotional support ($\alpha = 0.59$), and ability support ($\alpha = 0.72$). A relatively low internal consistency for emotional support has also been found in Chinese students (Duan et al., 2019; Fu, 2018), possibly because of the weakness of both expression and perception of emotion in Chinese culture.

Academic self-efficacy

The Academic Self-Efficacy Questionnaire was used to assess academic self-efficacy (Pintrich & De Groot, 1990), and the Chinese version of this scale showed good reliability and validity (Liang, 2000). It has 22 items: 11 items for academic ability self-efficacy (e.g., "I believe that I have the ability to get good grades in my study."); and 11 items for academic behavior self-efficacy (e.g., "I always listen carefully in class and don't think about anything else."). Each item was presented on a 5-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). A higher score on one dimension indicate a stronger sense of academic ability self-efficacy or academic behavior self-efficacy. For the current sample, the internal consistency of Cronbach's alpha of the total score was 0.89,

and good internal consistency characterized the subscales of academic behavior self-efficacy (α = 0.90), and academic ability self-efficacy (α = 0.80).

Learning engagement

The Learning Engagement Scale was used to assess learning engagement (Schaufeli et al., 2002), and the Chinese version of this scale showed good reliability and validity (Fang et al., 2008). It has 17 items: 6 items for vigor (e.g., "When I study, I feel full of energy."); 5 items for dedication (e.g., "I am very passionate about my study."); and 6 items for absorption (e.g., "When I studied, I forgot everything around me."). Each item was presented on a 7-point Likert-type scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Higher scores on one dimension indicate stronger student commitment to vigor, dedication or absorption. For the current sample, the internal consistency Cronbach's alpha of the total score was 0.95, and good internal consistency characterized the subscales of vigor (α = 0.86), dedication (α = 0.88), and absorption (α = 0.89).

Data analysis

In this study, a network model consisting of eight variables was estimated: three variables representing the three specific facets of perceived teacher autonomy support (i.e., learning support, emotional support and ability support), two variables representing the two specific facets of academic self-efficacy (i.e., academic ability self-efficacy and academic behavior self-efficacy), and three variables representing the three specific facets of learning engagement (i.e., vigor, dedication and absorption). The data were standardized for all variables.

To estimate the network, the qgraph package in R was used to establish a regularized partial correlation network, which can shrink very weak edges to zero (Epskamp & Fried, 2018). A visual graph of the network can be obtained, where the network graph consists of "nodes" of variables, and the connections between these nodes are called "edges". Blue edges indicate positive correlations between nodes, while red edges indicate negative correlations. The width and saturation of the edges indicate the strength of the correlations between pairs of nodes, with wider and more saturated edges indicating stronger correlations. The layout mechanism of the network graph is based on the Fruchterman-Reingold algorithm, which brings the more strongly correlated nodes closer together (Fruchterman & Reingold, 1991).

The centrality indices of each node are calculated to measure the importance of the node in the network structure. Since closeness and betweenness are not reliably estimated in psychological networks (Epskamp et al., 2018a), we only focused on strength for the centrality. Strength centrality of a node refers to the sum of the absolute values of all edges connected to that node within the network. And the networktools package in R was used to find bridge nodes, which are highly related to nodes from another constructs (Jones et al., 2021).

We also used the bootnet package in R to evaluate the accuracy and stability of the network. Following suggestions proposed by Epskamp et al. (2018a), we bootstrapped the 95% confidence intervals (CIs) of the edge weights to estimate the accuracy of the network edges. The larger the edge-weight CIs, the less accurate the edge weights. Then, we estimated the centrality stability coefficient (CS coefficient). The value of the CS coefficient should not be less than 0.25 and preferably higher than 0.5 (Epskamp et al., 2018a).

Results

The correlations between any two facets and the means and standard deviations of each facet are shown in Table 1. As we expected, all means were moderate. All correlations were significantly positive, but this cannot reveal whether there were causal connections between these facets. To explore the underlying causal paths, a network model was developed for the eight facets of perceived teacher autonomy support, academic self-efficacy and learning engagement.

The network is shown in Fig. 1. Of the 28 possible edges of the 8 nodes, only 11 edges were significant. All the 11 edges were positive, ranging from 0.13 to 0.48. The node pairs within a construct were all connected by edges. The top four strongest edges, i.e., "learning support-emotional support", "vigor-absorption", "learning support-ability support" and "dedication-absorption", were all from the interior of perceived teacher autonomy support and learning engagement. There were no edges between the three facets of perceived teacher autonomy support and the three facets of learning engagement, and the shortest path connecting the two constructs was through academic ability self-efficacy. Node F1 (academic ability self-efficacy) was at the center of the graph and had the most connections with nodes of other constructs.

The strengths of all nodes in the network are shown in Fig. 2. The node with the highest strength was E2 (devotion), followed by C1 (learning support) and F1 (academic ability self-efficacy), while the node with the lowest strength was C2 (emotional support). Nodes with higher strength have more or stronger connections with other nodes in the network. They are more predictive of other nodes in the network, are predicted by other nodes in the network, or both (Bringmann et al., 2019). Following the advice given by Jones et al. (2021), we selected bridge nodes by using an 80th percentile cutoff on the scores of bridge strength. Two bridge nodes, that is E2 and F1, were found in the network. It indicated that they were highly connected to other nodes in the network and linked perceived teacher autonomy support, academic self-efficacy, and learning engagement into one whole.

For the accuracy of the network, the bootstrap process for edge weights was run at 95% confidence intervals, as depicted in Fig. 3. The results showed that the bootstrap confidence intervals were small around most of the sample edge weights, and the bootstrap means of edge weights were close to the sample edge weights. These findings demonstrated the high accuracy of the network. Regarding the stability of the network, the case-dropping bootstrap procedure for node strengths was implemented. Average correlations between strengths in the full sample and the subsample with dropped cases were computed, and the 95% confidence intervals were also included. The results are shown in Fig. 4. The average correlations did not decline sharply as the sample size decreased, indicating the stability of node strengths. To further quantify the network stability, the CS coefficient was computed. The CS coefficient of our network was 0.749, higher than 0.5, indicating the good stability of our network.

Discussion

In this study, network analysis was applied to explore the relationships between specific facets of perceived teacher autonomy support, academic self-efficacy, and learning engagement. Then, the importance of each node in the network was estimated by node centrality

Table 1 Descriptive statistics and correlation matrix of perceived teacher autonomy support, academic self-efficacy and learning engagement (n = 215)

	Learning Support	Emotional Support	Ability Support	Academic Ability	Academic Behavior	Vigor	Dedication	Absorption
Learning Support	1.00							
Emotional Support	0.70***	1.00						
Ability Support	0.60***	0.52***	1.00					
Academic Ability	0.44***	0.44***	0.43***	1.00				
Academic Behavior	0.42***	0.43***	0.32***	0.74***	1.00			
Vigor	0.37***	0.42***	0.38***	0.71***	0.65***	1.00		
Dedication	0.45***	0.48***	0.72***	0.73***	0.71***	0.85***	1.00	
Absorption	0.44***	0.46***	0.41***	0.69***	0.65***	0.85***	0.86***	1.00
Mean	4.61	4.79	4.24	3.65	3.57	4.77	5.30	5.00
SD	0.83	1.05	1.54	0.91	0.66	1.53	1.56	1.63

*$p < 0.05$,**$p < 0.01$,***$p < 0.001$

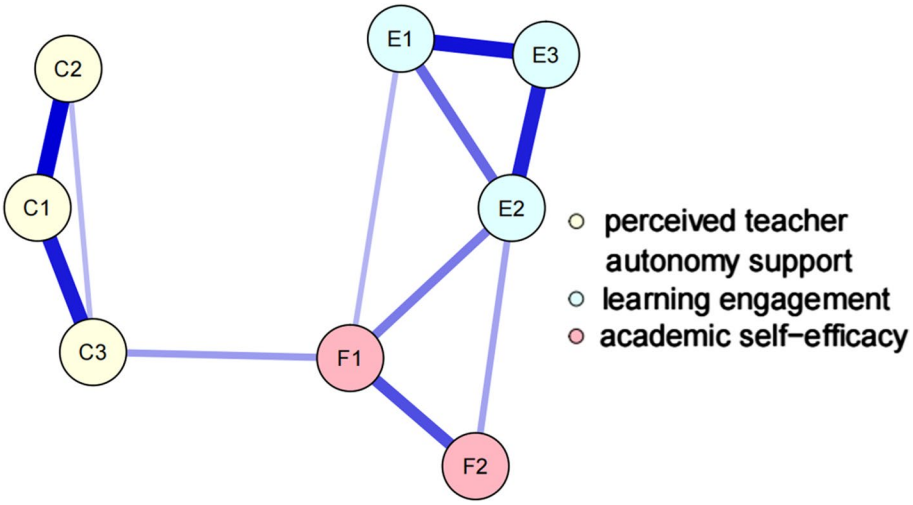

Fig. 1 The estimated network structure of different facets of perceived teacher autonomy support, academic self-efficacy and learning engagement. Blue edges represent positive correlations, and the thickness of the edges represents the magnitude of the correlations. "C1" = "learning support", "C2" = "emotional support", "C3" = "ability support", "E1" = "vigor", "E2" = "dedication", "E3" = "absorption", "F1" = "academic ability self-efficacy" and "F2" = "academic behavior self-efficacy"

indices, and the accuracy and stability of the network structure were tested. These results can provide new insights into the complex relationships between perceived teacher autonomy support, academic self-efficacy and learning engagement.

We found that all nodes in the network were positively correlated, which is similar to the results reported in previous studies (Fredricks et al., 2004; Kim et al., 2018; Wu et al., 2020). However, unlike previous studies, network analysis can exclude false marginal correlations induced by the covariation with a common node and indicate potential causal pathways, which are based on partial correlations rather than Pearson or rank correlations. Our network was sparse, where only 11 edges existed out of 28 possible edges. When there is no edge between two nodes, this means that the two nodes are independent after controlling for the other nodes in the network. The thickest edges were within, rather than between, constructs, which is in accordance with previous studies using network analysis for other psychological constructs (e.g., Levi-Belz et al., 2020; Wei et al., 2022). Throughout the network, none of the three facets of perceived teacher autonomy support had edges connected to the three facets of learning engagement, but were indirectly connected through academic self-efficacy.

From node centrality indices, the highest strength node, E2 (dedication), had both within- and between-construct connections, in keeping with previous research that found a strong relationship between academic self-efficacy and learning engagement (Lin, 2021; Putarek & Pavlin-Bernardić, 2020). The second highest strength node, C1 (learning support), only had within-construct connections, indicating its importance within perceived teacher autonomy support. The third highest strength node was F1 with both within- and between-construct connections. Nodes with higher strength have more or stronger connections with other nodes in the network and they may be located at the core of the network, indicating appropriate targets for interventions (Boschloo et al., 2015; Bringmann et al., 2019). Furthermore, E2 and F1 were the bridge nodes in the network.

In the network, perceived teacher autonomy support and learning engagement were separated by academic self-efficacy (more specifically F1). This means that perceived teacher

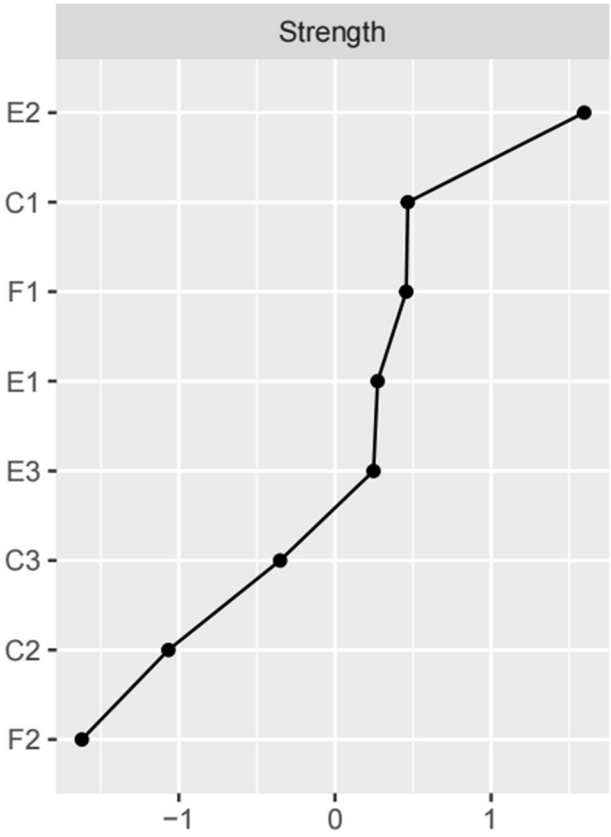

Fig. 2 The strengths of all nodes in the network (z-score)

autonomy support and learning engagement were independent given students' academic self-efficacy, and it indicates the important role of academic self-efficacy in the whole network. In accordance with the control value theory of achievement emotions, cognitive appraisals (including self-efficacy) may be influenced by the social environment created by teachers and can produce individual achievement emotions, learning and achievement (Ekatushabe et al., 2021; Pekrun, 2006). However, the causal directions of edges cannot be determined by network analysis. One possible causal explanation is the mediation effect of academic self-efficacy between perceived teacher autonomy support and learning engagement as stated in two previous studies (Jia et al., 2020; Liu et al., 2018). In addition, it is also possible that more engaged students may have higher self-efficacy and consequently ask for and receive more teacher support (Lin, 2021). Our results showed different network characteristics for the two facets of academic self-efficacy, that is F1 and F2. F1 was the bridge node and had the third highest strength, whereas F2 had the lowest strength. Furthermore, F2 had no edges connected with perceived teacher autonomy support. These novel findings indicate that F1 and F2 may play different roles in linking perceived teacher autonomy support and learning engagement, which cannot be discovered by treating them as a whole construct.

The present study contributes to understand in more specific detail the potential pathways that can promote learning engagement, which can serve to formulate initial hypotheses about which facets of perceived teacher autonomy support (distal) and academic self-efficacy (proximal) are potential targets for future psychological interventions. Further, because different associations of facets within a construct were uncovered, it helps us to

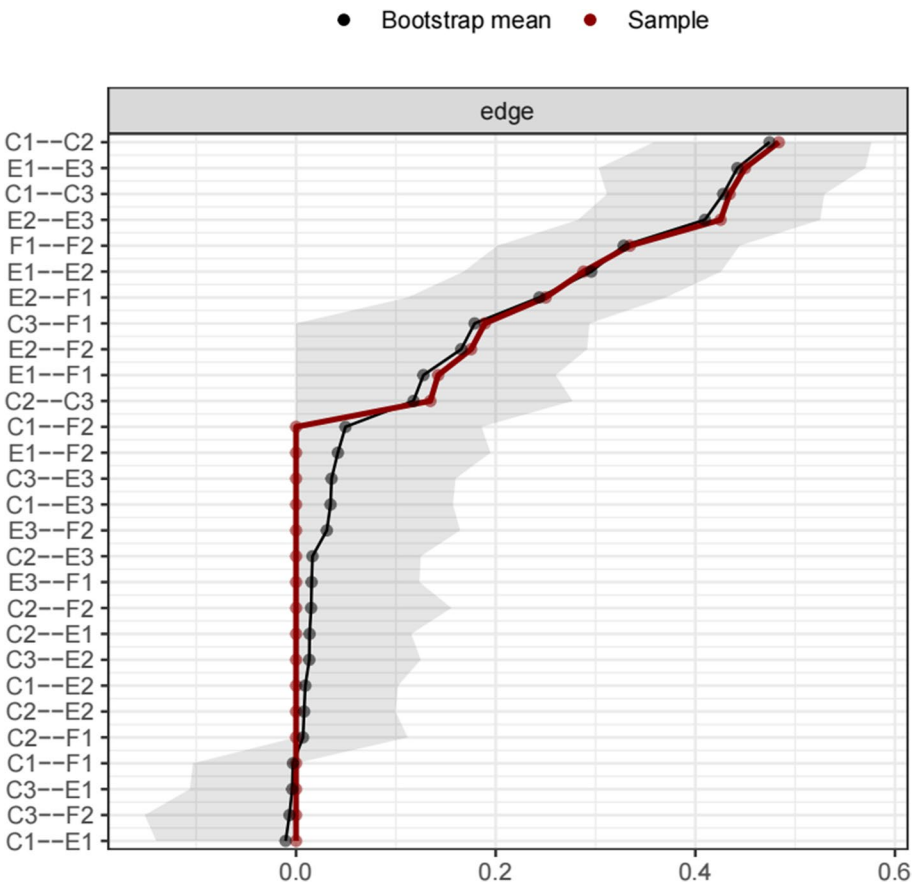

Fig. 3 Bootstrap confidence intervals of estimated edge weights. The red line indicates the sample values (sorted in descending order), the gray area indicates the bootstrap confidence intervals, and the black line indicates the means of the bootstrap samples

better understand the components of a psychological construct. Lastly, we found that perceived teacher autonomy support was connected to only one facet of academic self-efficacy. This can stimulate further studies to examine whether perceived teacher autonomy support has distinct effects on different facets of academic self-efficacy.

Some limitations of this study have implications for future research. First, the network analysis in our study is based on cross-sectional data, which hinders precise causal inferences compared to time series or panel data. The cross-sectional network can generate hypotheses about the prediction, direction, or causality between different nodes (Epskamp et al., 2018b), and this needs further study with time-series data. Second, the reliability of the Student Perceived Teacher Support Behavior Questionnaire was a little low, which may affect the replicability of our network study. Third, our participants came from multiple classes at one school, and may have been taught by different teachers. Additionally, other sociodemographic variables, such as socio economic status, were not included in our study. These factors may affect the results of network analysis and should be examined in future research. Finally, our participants were from the same school and may not be representative of students in other schools in

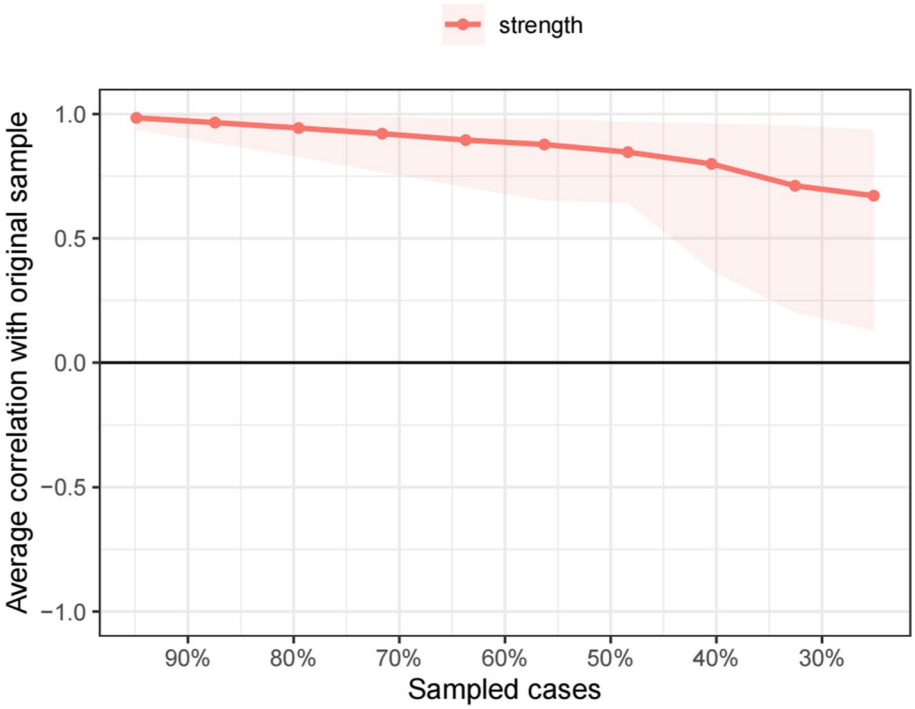

Fig. 4 Average correlations between node strengths in the full sample and subsample with dropped cases. The red line indicates the means and the red area indicates the 95% bootstrap confidence intervals

China or other cultural contexts. Futher research is needed with other representative samples and populations to increase the generalisability of the results of our study.

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Declarations

Competing interests The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Current themes of research:

Zixu Hu: Self-efficacy. Learning engagement. Network analysis.
Na Shan: Network analysis. Causal inference. Item response theory.
Runkai Jiao: Self-determination theory. Occupational Engagement.

Most relevant publications in the field of Psychology of Education: Zixu Hu: No previous publications.

Na Shan: No previous publications.
Runkai Jiao: Wang, P., Zhang, L., Wang, X., Geng, J., Gao, X., Ma, J., & Jiao, R. (2018). Career exploration and decision self-efficacy scale: factorial structure and validity. *Journal of College Student Development*, 59(4), 475–478. https://doi.org/10.1353/csd.2018.0043