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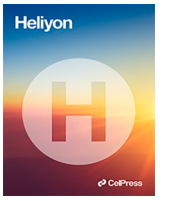

Research article

Factors influencing innovation competence among children and adolescents in China – A multilevel, cross-cohort study

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ABSTRACT

Innovation competence is an essential core literacy skill for 21st century students. While some research exists on innovation competence in college students, there has been relatively little examination of the factors influencing this competence in children and adolescents aged 10 to 15. This study evaluated innovation competence among students from Suzhou, China, focusing on four key social and emotional skills: creativity, curiosity, cooperation, and responsibility. Data from the Organization for Economic Cooperation and Development were utilized for this analysis. Hierarchical linear modelling was applied to analyze potential factors at both individual and school levels influencing innovation competence across family and school environments. We calculated a *t*-test statistic to compare factors between the two cohorts. Factors significantly influencing children and adolescents' innovation competence included socio-economic status, time spent engaging in online gaming, time spent browsing the Internet for information, and the perceived cooperative climate atschool. Gender significantly influenced only adolescents' innovation competence, while teachers' disruptive behaviors had an impact solely on children's innovation competence. Apart from time spent engaging in online gaming and browsing the Internet for information, the effects of other variables showed significant differences between the groups. The findings highlight the need for targeted support from families, schools, and society to foster students' innovation competence.

1. Introduction

Innovation competence is widely acknowledged as a crucial driver for sustainable development within organizations [1]. This concept is rooted in the notion that individual innovation competence is pivotal for fostering organizational innovation [2], defined as an individual's ability to generate solutions that are original, appropriate, and actionable in response to challenges or tasks in specific contexts [3,4]. Hero et al. expanded on this by conceptualizing innovation competence as a blend of personal traits, knowledge, skills,

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and attitudes, which collectively facilitate the creation of tangible innovations through collaborative processes [5]. Emphasizing the significance of nurturing the innovation competence of today's youth, Robinson [6] argued that their skills are fundamental to future societal progress, advocating for effective educational strategies to cultivate these competencies, a view supported by various scholars and agencies [7–9].

The construct of innovation competence is central to this study, as innovation competence has been associated specifically with "sustainability" in firm performance [10] and social development [11]. Drawing from Bozic's integrated model [12] and Janssen's insights [13], which outline innovation behavior as encompassing idea generation, promotion, and realization, we assess four critical constructs—creativity, curiosity, cooperation, and responsibility. Creativity is essential for ideation [14], while curiosity drives the quest for new knowledge [15]. Cooperation is crucial during idea promotion, emphasizing strong interpersonal relationships, and responsibility is key in idea realization, aligning innovations with organizational goals and ethical standards [12].

Educational systems, which typically group students by age, must adapt their approaches to foster innovation competence, considering the developmental differences between children and adolescents [9,16–19]. While higher education has seen numerous initiatives to enhance student innovation competence [17,20,21], basic education, encompassing primary and secondary levels, has received less attention despite its critical role in shaping the capabilities of young minds[22,23]. Researchers highlighted barriers for young learners such as low-quality curriculum and traditional teaching methods [24], but also pointed to the potential of supportive learning environments [25,26]. The need for a systematic approach to fostering creativity and innovation competence from a young age has been emphasized [6,27], underscoring the importance of research focused on the basic education stage [27].

Among the limited literature on nurturing innovation competence in elementary school students, the majority of existing studies concentrate on school-based factors, such as the learning environment [28] and classroom safety perceptions [29]. Yet, the critical influence of the family in shaping young minds is undeniable [30]. A holistic approach that encompasses both family and school factors is crucial for a comprehensive understanding of students' innovation competence. Acknowledging the interaction between these elements is key to designing effective interventions for fostering innovation competence.

Bandura's social cognitive theory (SCT) provides an insightful framework to navigate the intricacies of factors that mold a young learner's innovative competence. This theory characterizes human behavior as a synergy of personal attributes, specific behaviors, and environmental contexts [31]. When applied to young learners' innovation competence, personal attributes include elements like preferences, beliefs, and motivational factors which are intricately tied to aspects like gender [32–34]. Concurrently, behaviors involve the actions of students which can either bolster or hinder innovation competence, and the pedagogical activities of educators. Lastly, the environmental dimension bridges both the home and school atmospheres. Drawing from this SCT foundation, it is evident that cultivating innovative competence is a complex process, melding individual, familial, and educational components. A notable gap exists in research that holistically examines these intertwined influences, particularly for children and adolescents, using the SCT perspective.

To address this gap, this study utilized data from the OECD's 2019 Survey on Social and Emotional Skills (SSES) to perform a multilevel analysis of potential individual, family, and school factors affecting innovation competence at both student and school levels. This analysis aimed to deeply explore the development of innovation competence among young learners, using SSES data from 2018 to 2019 to assess the social and emotional skills of two age groups: 10- and 15-year-old students from ten cities [35]. The current study assesses innovation competence through four key constructs: creativity, curiosity, cooperation, and responsibility. These constructs serve as indicators of students' innovation competence, guiding the analysis of potential influencing factors. The SSES 2021 report revealed that 15-year-olds generally exhibited lower innovation competence levels than 10-year-olds [36]. Notably, the gap in innovation competence, particularly in creativity and curiosity, between children and adolescents in Suzhou was significantly larger than in other participating regions, suggesting age-related differences in influencing factors [36].

Building upon earlier discussions, this study sets itself apart in several ways: Unlike the prevailing focus on college students' innovation competence in literature [17,20,21], we center our investigation on children and adolescents, acknowledging their developmental plasticity. Current research predominantly targets the factors within educational settings that shape innovation competence [28,29], however, our approach pivots towards understanding the influences of innovative competence in younger learners through the lens of SCT. Additionally, with the SSES data indicating marked differences in innovative competences between children and adolescents [36], an integral objective is to explore whether these influences have differential impacts across these age groups—a perspective largely absent in extant research.

To offer targeted recommendations for enhancing innovation competence among young learners, this study draws on data from Suzhou, China, provided by the OECD's Survey on SSES. It conducts an in-depth analysis of both student- and school-level factors. Grounded in SCT, the research examines gender as a personal attribute, while considering students' online behaviors and educators' teaching behaviors as behavioral influences. Additionally, it identifies family socio-economic background and the school's collaborative environment as critical factors from both home and educational settings. The core aim is to evaluate the combined impact of these elements—gender, socio-economic status, digital engagement (i.e., time spent engaging in online gaming and browsing the Internet for information), perceived cooperative climate at school, and teachers' disruptive behaviors—on the innovation competence of young learners. Furthermore, the study seeks to uncover any variance in these effects between two key age groups: 10- and 15-year-olds, thereby providing a nuanced understanding of how these factors contribute to developing innovation competence at different stages of childhood and adolescence.

2. Literature review

In this section, we begin by summarizing the initial findings related to the four dimensions of innovation competence in the SSES

report, which is then followed by a presentation of the research hypotheses.

2.1. Initial findings of innovation competence in the SSES

The SSES is an international assessment that evaluates the social and emotional skills of children and adolescents at ages 10 and 15 years [35,36]. According to an OECD report [36], the four dimensions of students' innovation competence in this study (i.e., creativity, curiosity, cooperation and responsibility) are influenced significantly by gender and family socio-economic status which is a composite index based on data from parental education, occupation, and home possessions [35]. In other words, these two factors can have substantial influences on students' innovation competence. The OECD report indicates that the self-reported values of 10-year-old girls are generally higher than those of boys in most participating countries or regions, while the self-reported values of 15-year-old boys are notably higher than those of girls in Suzhou, China. Furthermore, regardless of gender, students from higher socio-economic backgrounds have been found to exhibit higher innovation competence [36].

2.2. Research hypotheses

According to the SCT framework and drawing from prior studies, we selected five student-level variables – gender [37–40], socio-economic status [41–44], time spent engaging in online gaming [45–47], time spent browsing the Internet for information [48], and perceived cooperative climate at school [49], as well as one school-level variable – teachers' disruptive behaviors [50], which together were identified as explanatory variables. Since different class sizes can affect the development of innovation competence among students [51,52], the variable of class size at the school level was controlled for in this study.

2.2.1. Gender

In this study, gender is included because there is ongoing debate as to the existence of gender differences in innovation competence, as noted in the SSES report [36]. Furthermore, gender should be considered in light of SCT, since it is associated with individual characteristics [32–34]. While some studies have found significant differences between males and females in creativity [38–40,53], curiosity [54,55], cooperation [56] and responsibility [57], others have found no significant differences in innovation competence between genders [58–60]. Given these conflicting results, more empirical evidence is required. The following hypotheses are therefore proposed.

H1a. Gender has a significant influence on children's innovation competence.

H1b. Gender has a significant influence on adolescents' innovation competence.

Moreover, existing research has indicated that creativity varies by gender among children and adolescents. Employing descriptive statistics such as mean and variance, He et al. [61] investigated the dynamic relationship between gender and creativity from a developmental standpoint. Based on mean analysis, gender differences were found to be generally minor, with an advantage for females apparent only in childhood, and no significant gender difference during adolescence. However, regarding the variance, the results revealed substantial gender differences across ages, with females in the children group exhibiting greater variance and males in the adolescent group displaying greater variance. In a follow-up study, He [62] expanded upon this examination of creativity through a four-year longitudinal study from the perspective of the developmental theory of gender differences in intelligence. The findings suggested a dynamic pattern of gender differences in intellectual abilities, transitioning from higher levels among females during childhood and early adolescence to higher levels among males from 16 years of age. Furthermore, concerning creativity, females were found to demonstrate higher levels during childhood and early adolescence, whereas males did not show a comparable advantage during adolescence (i.e., over age 16). Consequently, gender may have differing influences on students' innovation competence at various ages. Accordingly, the present study proposed the following hypothesis.

H1c. The influence of gender on innovation competence differs significantly between children and adolescents.

2.2.2. Socio-economic status

The effect of socio-economic status on students' innovation competence has been established in previous empirical studies [42–44,63], with students from higher socio-economic backgrounds benefitting from increased family economic and cultural capital and having access to a greater array of learning facilities and resources, potentially resulting in heightened creativity [42–44,63]. Additionally, research has indicated that children with higher socio-economic status are more likely to receive parental encouragement to be curious [64]. Thus, based on these findings, we proposed the following hypotheses.

H2a. Children with higher socio-economic status exhibit greater innovation competence.

H2b. Adolescents with higher socio-economic status exhibit greater innovation competence.

Moreover, the influence of the social environment can intensify with age, and may even progressively surpass the impact of family on adolescents [65,66]. This is attributed to the gradually diminishing influence of family from childhood to adolescence [67]. Conversely, the social environment, which encompasses school, peers, and community, increasingly affects teenagers [68,69]. Based on these observations, we proposed the following hypothesis.

H2c. The influence of socio-economic status on innovation competence differs significantly between children and adolescents.

2.2.3. Time spent engaging in online gaming

Online gaming has emerged as a widespread activity among students, gaining considerable popularity even among young children [48]. Existing literature reveals a dichotomy in scholarly perspectives concerning the influence of online gaming on students' innovative competencies [46,47,70]. For instance, Granic et al. [46] discovered that video gaming bolsters creativity in children and adolescents. In contrast, other research has identified a decrease in creativity among students who frequently participate in online gaming [70].

Given the inconsistency in findings pertaining to the influence of time dedicated to online gaming on innovative competencies, there is a need for additional empirical evidence. Consequently, this study proposes the following hypotheses.

H3a. Time spent engaging in online gaming significantly influences the innovative competencies of children.

H3b. Time spent engaging in online gaming significantly influences the innovative competencies of adolescents.

The basis for the conjecture that this behavior may differently impact innovative competencies lies in the distinction between children and adolescents. Specifically, adolescents have been found to possess more advanced cognitive control in response to potential stressors, such as increased academic demands or peer competition [71,72]. This heightened cognitive control may enable adolescents to counteract any potential negative influences on innovation resulting from online gaming. As such, the subsequent hypothesis was proposed.

H3c. There is a significant difference in the influence of time spent engaging in online gaming on the innovative competencies between children and adolescents.

2.2.4. Time spent browsing the internet for information

Students increasingly acquire information and knowledge via the Internet, which is attributable to the widespread accessibility of electronic devices and the pervasiveness of the Internet [73]. It is reasonable to assert that browsing the Internet for information can expand students' horizons and stimulate their imagination [74]. The information gleaned can foster students' curiosity, thereby motivating them to continue browsing the Internet. Concurrently, students may be encouraged to explore and resolve novel problems with enhanced responsibility. Evidence indicates that utilizing the Internet to obtain current information can positively influence students' self-efficacy [75], which correlates positively with creativity [76]. Given that curiosity, creativity and responsibility are dimensions of innovative competence, it is postulated that time spent browsing the Internet for information can positively affect students' innovative competence. Consequently, the following exploratory hypotheses are proposed.

H4a. Time spent browsing the Internet for information positively influences children's innovative competence.

H4b. Time spent browsing the Internet for information positively influence adolescents' innovative competence.

As mentioned previously, browsing the Internet for information can prompt students to approach problem-solving with greater responsibility. In other words, engaging in problem-solving while browsing the Internet for information can foster responsibility and, as responsibility is a crucial attribute of innovative competence, will contribute positively to innovative competence. Considering that problem-solving abilities progressively improve with the development of cognitive control, and adolescents exhibit a higher degree of cognitive control [72,77,78], it is reasonable to assume that browsing the Internet for information will have a more pronounced influence on their innovative competence. Thus, the following hypothesis is proposed.

H4c. There is a significant difference in the influence of time spent browsing the Internet for information on innovative competence between children and adolescents.

2.2.5. Perceived cooperative climate at school

Perceived cooperative climate at school refers to students' perceptions of mutual cooperation and the value of collaboration among their peers [35]. A cooperative atmosphere at school can enhance a student's sense of belonging and security [79], fostering teamwork and building cooperation with others, which is essential for the development of innovative competence. Previous research has indicated that students' perception of the cooperative climate at school directly affects their innovative competence through engagement in teamwork [80]. In 1949, social psychologist Morton Deutsch, who specialized in educational environments, determined that cooperative students were more likely to facilitate their own and others' learning [80]. Students' cooperative learning aids in cultivating cooperation and curiosity in problem-solving [81], and can positively impact their motivation to learn as well as their capacity to develop creative thinking and problem-solving skills [82]. Since cooperation, curiosity and creativity constitute components of innovative competence, the perceived cooperative climate at school can bolster students' innovative competence. Therefore, the following hypotheses are proposed.

H5a. The perceived cooperative climate at school positively influences the innovative competence of children.

H5b. The perceived cooperative climate at school positively influences the innovative competence of adolescents.

Furthermore, it is anticipated that the influence of the perceived cooperative climate at school on innovation competence will vary between children and adolescents. This could be attributed to the fact that adolescents, in comparison to children, generally exhibit greater independence and self-awareness [83], rendering them less susceptible to peer influence. As a result, the perceived cooperative climate at school may exert a less pronounced influence on the innovation competence of adolescents. Thus, the subsequent hypothesis

was posited.

H5c. The influence of the perceived cooperative climate at school on innovation competence differs significantly between children and adolescents.

2.2.6. *Teachers' disruptive behaviors*

As delineated by Kearney et al. [84], teacher misbehavior can be conceptualized into three dimensions: teacher incompetence, teacher offensiveness, and teacher indolence. With regards to the SSES, teachers' disruptive behaviors pertain to the incompetence and indolence dimensions of their misbehavior, typically manifesting as a deficiency in fundamental teaching skills and "absent-minded" instruction [35]. Past studies with college students have demonstrated associations between teacher misbehavior and diminished affective learning [85], decreased motivation for tutor communication [86], and reduced student interest and engagement [50]. Teacher incompetence has been shown to predict student interest [50], suggesting that teachers' disruptive behavior can attenuate student interest, thereby stifling curiosity and inhibiting the generation of innovative ideas [87]. Given that creativity and curiosity are vital components of innovation competence, teachers' disruptive behavior may impede the cultivation of innovation competence in students. Considering the heightened susceptibility of children and adolescents to teachers' disruptive behavior compared to college students, the following hypotheses are proposed.

Table 1
Variables in the Model and reliability, validity of constructs.

	Variables	Corresponding SSES items	Cronbach's alpha	CR	AVE
Dependent variable	Innovation competence	Creativity (CRE_WLE_ADJ)			
		STA_CRE01	0.76[a]/0.82[b]	0.82[a]/	0.44[a]/
		STA_CRE02		0.77[b]	0.37[b]
		STA_CRE04			
		STA_CRE05			
		STA_CRE06			
		STA_CRE07			
		Curiosity (CUR_WLE_ADJ)			
		STA_CUR02	0.77[a]/0.8[b]	0.81[a]/	0.42[a]/
		STA_CUR04		0.78[b]	0.38[b]
		STA_CUR05			
		STA_CUR06			
		STA_CUR07			
		STA_CUR08			
		Cooperation (COO_WLE_ADJ)			
		STA_COO01	0.82[a]/0.81[b]	0.81[a]/	0.39[a]/0.4[b]
		STA_COO02		0.82[b]	
		STA_COO03			
		STA_COO04			
		STA_COO06			
		STA_COO07			
		STA_COO08			
		Responsibility (RES_WLE_ADJ)			
		STA_RES01	0.74[a]/0.8[b]	0.8[a]/0.74[b]	0.4[a]/0.33[b]
		STA_RES03			
		STA_RES04			
		STA_RES05			
		STA_RES06			
		STA_RES08			
Independent variable (student-level)	Gender	Gender_Std	–	–	–
	Socio-economic status	SES	–	–	–
	Time spent engaging in online gaming	STQM03606	–	–	–
	Time spent browsing the Internet for information	STQM03610	–	–	–
	Perceived cooperative climate at school	STQM03801 - STQM03802	0.84[a]/0.89[b]	–	–
Independent variable (school-level)	Teachers' disruptive behaviors	PR_TEABEHA			
		PRQM02701- PRQM02706	0.95[a]/0.95[b]	0.95[a]/	0.75[a]/
				0.96[b]	0.78[b]
Control variable (school-level)	Class size	PRQM00601	–	–	–

CR = Composite Reliability, AVE = Average Variance Extracted. All the above-mentioned English codes were drawn from the Survey on Social and Emotional Skills technical report [35].

*Note.

[a] 10-year-old student cohort.

[b] 15-year-old student cohort.

H6a. Teachers' disruptive behavior exerts a negative influence on the innovation competence of children.

H6b. Teachers' disruptive behavior exerts a negative influence on the innovation competence of adolescents.

In light of the disparities in teachers' disruptive behavior toward children and adolescents, this study postulated that the influences of teachers' disruptive behavior on students' innovation competence would differ between these two age groups. This divergence could stem from children's decreasing reliance on parental supervision upon entering school and their corresponding increased susceptibility to external influences [83]. Conversely, as adolescents progress toward greater independence and autonomy, teachers' influence diminishes. One study has indicated that adolescents often encounter difficulties in forging close relationships with teachers due to junior high school structures (e.g., frequent teacher changes or interactions between teachers and students that revolve primarily around academic content) [83]. Consequently, we posit that teachers' disruptive behavior would have a less significant influence on the innovation competence of adolescents than on that of children. Thus, the following hypothesis was proposed.

H6c. The influence of teachers' disruptive behavior on innovation competence differs significantly between children and adolescents.

3. Method

3.1. Data source

The data used for analysis in this study was derived from the raw data obtained from the SSES. Comprehensive information on the SSES can be found at *https://www.oecd.org/education/ceri/social-emotional-skills-study/data.htm*. Ethics committee approval does not pertain to our study as the utilized data was procured from the SSES, conducted by the OECD. Given that this survey did not encompass any experiments involving human subjects or animals, the OECD, in its capacity as the survey's governing entity, did not furnish any details on ethical approval. Data was selected from students and principals in Suzhou, China, yielding a sample of 7,246 students and 150 principals for data analysis. After excluding cases with incomplete information and eliminating errors of omission during the matching process – where variables from the school and student levels were matched through School ID – a total of 6,965 students and 146 principals were deemed valid for analysis. The sample consisted of 3,562 students in the 10-year-old cohort and 3,403 in the 15-

Table 2
Factor loadings of constructs in EFA and CFA of the 10-year-old cohort.

Construct	Item	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
		EFA	CFA	EFA	CFA	EFA	CFA	EFA	CFA	EFA	CFA
Creativity	STA_CRE01	0.419	0.68	0.189		0.055		−0.048			
	STA_CRE02	0.646	0.781	0.053		0.056		−0.062			
	STA_CRE04	0.518	0.646	0.065		0.094		−0.075			
	STA_CRE05	0.736	0.749	−0.079		−0.001		0.01			
	STA_CRE06	0.585	0.565	−0.12		0.108		−0.016			
	STA_CRE07	0.534	0.525	−0.171		−0.192		0.42			
Curiosity	STA_CUR02	0.056		0.662	0.628	−0.005		0.035			
	STA_CUR04	0.53		0.165	0.627	−0.008		−0.054			
	STA_CUR05	0.295		0.385	0.718	0.052		−0.023			
	STA_CUR06	−0.116		0.576	0.601	−0.12		0.305			
	STA_CUR07	0.122		0.572	0.734	0.101		−0.001			
	STA_CUR08	0.317		0.129	0.556	0.045		0.028			
Cooperation	STA_COO01	0.023		0.031		0.623	0.691	−0.018			
	STA_COO02	−0.002		0.082		0.558	0.619	0.017			
	STA_COO03	0.211		0.117		0.415	0.662	−0.03			
	STA_COO04	−0.012		−0.04		0.213	0.412	0.424			
	STA_COO06	0.054		−0.145		0.782	0.726	−0.002			
	STA_COO07	0.002		−0.133		0.815	0.645	−0.022			
	STA_COO08	0.027		0.14		0.47	0.561	0.091			
Responsibility	STA_RES01	−0.025		0.113		−0.012		0.345	0.582		
	STA_RES03	−0.059		0.055		0.016		0.574	0.585		
	STA_RES04	−0.154		0.116		0.14		0.521	0.666		
	STA_RES05	0.027		0.049		0.494		0.209	0.618		
	STA_RES06	0.093		0.13		0.403		0.195	0.74		
	STA_RES08	0.119		0.004		−0.057		0.614	0.598		
Teachers' disruptive behavior	PRQM02701									0.791	0.772
	PRQM02702									0.859	0.884
	PRQM02703									0.884	0.857
	PRQM02704									0.879	0.856
	PRQM02705									0.899	0.919
	PRQM02706									0.895	0.906

*_Note:_ EFA = Exploratory Factor Analysis, CFA = Confirmatory Factor Analysis. All the above-mentioned English codes were drawn from the Survey on Social and Emotional Skills technical report [35].

year-old cohort. The younger student cohort was comprised of 1,626 girls and 1,936 boys, while the older student cohort consisted of 1,664 girls and 1,739 boys. The corresponding numbers of schools for the two cohorts were 75 and 71, respectively. Given that data from principals was only utilized to measure school-level variables, the principals' personal background variables were not the focus of this study and, therefore, will not be discussed in subsequent sections.

3.2. Measures

Table 1 displays the variables employed in the hierarchical linear modelling (HLM), along with the SSES measurement indicators for each variable (see Table S1 for a full list of items). This study incorporated three distinct types of indices. The first pertains to innovation competence and teachers' disruptive behaviors. Innovation competence was calculated as the average of four variables: creativity (CRE_WLE_ADJ), curiosity (CUR_WLE_ADJ), cooperation (COO_WLE_ADJ) and responsibility (RES_WLE_ADJ) drawn from student-level data. The variable for teachers' disruptive behavior was drawn from principals' data. Variables such as creativity, curiosity, cooperation, responsibility, and teachers' disruptive behavior were computed by the SSES project team using the Item Response Theory (IRT) scaling model to calculate the estimations, deriving SSES scale scores and estimated adjusted scale scores. The second type of index was the composite index, including socio-economic status in the student questionnaire. This measure is based on the highest level of parental occupation, parental education, and household possessions. This index was constructed using factor scores emerging from Principal Component Analysis. For a more detailed calculation methodology, refer to Ref. [35]. The third index encompassed original items such as gender (Gender_Std), time spent engaging online gaming (STQM03606), time spent browsing the Internet for information (STQM03610), and perceived cooperative climate at school, which was the average of two original items, STQM03801 and STQM03802. Moreover, given that class size (PRQM00601) may influence students' innovation competence [51,52], this was utilized as a control variable in the study. Detailed descriptions of the variables' measurements are provided in Table 1.

3.2.1. Innovation competence

Drawing from the SSES, innovation competence in this study was derived from a composite dataset of creativity, curiosity, cooperation and responsibility constructs. The SSES featured six items each for creativity, curiosity and responsibility, and seven items for cooperation. All items were rated using a five-point Likert scale (1 = Strongly disagree, 2 = Disagree, 3 = Neither agree nor disagree, 4 = Agree, 5 = Strongly agree). Students with higher scores on these constructs exhibited greater innovation competence.

Table 3
Factor loadings of constructs in EFA and CFA of the 15-year-old cohort.

Construct	Item	Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
		EFA	CFA	EFA	CFA	EFA	CFA	EFA	CFA	EFA	CFA
Creativity	STA_CRE01	0.638	0.596	0.002		0.009		0.042			
	STA_CRE02	0.82	0.708	−0.064		−0.039		0.045			
	STA_CRE04	0.68	0.598	−0.001		−0.02		−0.052			
	STA_CRE05	0.735	0.659	0.036		0.059		−0.079			
	STA_CRE06	0.623	0.565	−0.11		0.071		−0.056			
	STA_CRE07	0.546	0.47	−0.03		−0.191		0.242			
Curiosity	STA_CUR02	0.007		0.635	0.668	−0.004		0.074			
	STA_CUR04	0.435		0.285	0.566	0.019		−0.058			
	STA_CUR05	0.349		0.43	0.664	0.055		−0.072			
	STA_CUR06	−0.118		0.732	0.534	−0.11		0.217			
	STA_CUR07	0.021		0.678	0.736	0.166		−0.071			
	STA_CUR08	0.297		0.353	0.467	0.01		−0.09			
Cooperation	STA_COO01	−0.001		0.043		0.685	0.642	−0.035			
	STA_COO02	0.116		−0.075		0.519	0.637	0.081			
	STA_COO03	0.192		−0.073		0.494	0.655	0.125			
	STA_COO04	−0.06		0.016		0.18	0.465	0.387			
	STA_COO06	−0.081		0.007		0.851	0.68	−0.079			
	STA_COO07	−0.068		0.024		0.745	0.667	−0.09			
	STA_COO08	−0.065		0.092		0.458	0.662	0.14			
Responsibility	STA_RES01	0.018		0.02		0.01		0.576	0.354		
	STA_RES03	−0.054		0.027		−0.054		0.692	0.48		
	STA_RES04	0.014		0.09		−0.004		0.649	0.53		
	STA_RES05	0.047		−0.042		0.409		0.283	0.724		
	STA_RES06	0.072		−0.023		0.343		0.423	0.749		
	STA_RES08	0.023		0.017		−0.069		0.685	0.532		
Teachers' disruptive behavior	PRQM02701									0.769	0.747
	PRQM02702									0.956	0.970
	PRQM02703									0.893	0.866
	PRQM02704									0.832	0.836
	PRQM02705									0.91	0.935
	PRQM02706									0.943	0.929

*_Note:_ EFA = Exploratory Factor Analysis, CFA = Confirmatory Factor Analysis. All the above-mentioned English codes were drawn from the Survey on Social and Emotional Skills technical report [35].

The dataset was analyzed using both Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) before any further analysis. EFA was conducted using the Principal Axis Factoring technique combined with a Promax rotation. The factor loadings resulting from EFA and CFA for the two cohorts are provided in Table 2 and Table 3, respectively. To determine convergent validity and examine reliability, the Average Variance Extracted (AVE), Composite Reliability (CR), and Cronbach's alpha values [88] for the four constructs (namely, creativity, curiosity, cooperation and responsibility) and the teachers' disruptive behavior are presented in Table 1. The results indicate that only a few items for the two cohorts did not align with the factors as defined by the SSES. Given the inherent relationship among the four variables in relation to innovative behaviors, this discrepancy is acceptable. Moreover, the values of AVE, CR, and Cronbach's alpha all support the robust reliability and validity of our study. As shown in Table 1, the Cronbach's alpha values for the four constructs are all above 0.7, indicating good reliability [89]. All four constructs have AVEs below 0.5 but CRs above 0.6, which, according to Fornell and Larcker [90], suggests satisfactory convergent validity.

Additionally, a higher-order CFA was conducted for the two distinct cohorts: the 10-year-old cohort and the 15-year-old cohort. For the 10-year-old cohort, the coefficients derived from the higher-order factor for creativity, curiosity, cooperation, and responsibility were 0.82, 0.94, 0.94, and 0.88, respectively. For the 15-year-old cohort, the corresponding coefficients were 0.74, 0.87, 0.85, and 0.75. The measurement model of innovation competence exhibited a satisfactory fit for both cohorts. For the 10-year-old cohort: CFI = 0.983, TLI = 0.981, NFI = 0.980, RMSEA = 0.036, and SRMR = 0.042. For the 15-year-old cohort: CFI = 0.969, TLI = 0.966, NFI = 0.966, RMSEA = 0.048, and SRMR = 0.053. These results suggest that the higher-order factor of innovation competence effectively represented the four subordinate factors.

3.2.2. Time spent on the internet

To measure students' time spent on the Internet, the SSES employed two items: "Time spent engaging in online gaming" (Item STQM03606) and "Time spent browsing the Internet for information" (Item STQM03610). Both items are rated on a four-point scale (1 = No time, 2 = 1–60 min per day, 3 = Between 1 and 4 h per day, and 4 = More than 4 h per day). Higher scores indicate increased daily online use for the noted purpose.

3.2.3. Perceived cooperative climate at school

The SSES measured students' perceived cooperative climate at school using two items: "Students seem to value cooperation" and "It seems that students are cooperating with each other." Responses were rated on a four-point scale (1 = Almost never true, 2 = Sometimes true, 3 = Often true, and 4 = Almost always true. The variable of perceived cooperative climate at school was calculated based on the average of these two items, with higher final scores representing a heightened perception of a cooperative climate within the student's school. When the two items were tested for internal consistency, Cronbach's alpha values of 0.84 and 0.89 for the two cohorts indicated acceptable consistency reliability.

3.2.4. Teachers' disruptive behavior

In the SSES questionnaire for principals, teachers' disruptive behavior towards students was assessed using a four-point Likert scale: 1 = Very little, 2 = Little, 3 = To some extent, and 4 = A great deal. Given the stringent societal expectations concerning teachers' morals and the severe implications of their disruptive behavior, it is plausible that principals may provide more candid responses than teachers when surveyed. Consequently, principals, rather than the teachers themselves, were tasked with evaluating the prevalence of teachers' disruptive behavior across six items in the SSES. AVE and CR are displayed for the two cohorts in Table 1 and factor loadings for EFA and CFA are presented in Table 2 and Table 3 for the two cohorts. The results of EFA and CFA indicated a one–factor structure. Based on Table 1, the AVEs were higher than 0.5 and the CRs were greater than 0.9, which confirms the convergent validity of this construct. The SSES project team processed PR_TEABEHA as the measurement indicator for teachers' disruptive behavior. Higher scores indicated more severe disruptive behavior from the teacher. Internal consistency tests produced Cronbach's alphas of 0.95 for both the younger and older cohorts, reflecting good internal consistency reliability.

3.3. Data analysis strategy

In this study, through the lens of SCT, we identified factors influencing innovation competence from variables across different levels (e.g., gender, socio-economic status at the individual level, teachers' disruptive behavior at the organizational level). Given the multi-level nature of these factors, HLM was employed as the primary method for integrating and analyzing data across these levels. Specifically, our data analysis strategy included descriptive statistical analysis, HLM, and cross-group comparisons. We began by applying descriptive statistics to present the mean (and standard deviation) or frequency distribution of variables at both the student and school levels, in addition to computing Pearson correlations for student-level variables. These initial analyses were conducted using SPSS version 25.0.

Secondly, in response to the nested structure of the SSES datasets, HLM 6.08 was applied to test the hypotheses [91]. Following the approach outlined by Raudenbush and Bryk [92], the Intercepts as Outcomes Model was implemented to examine the influence of school-level and student-level variables on students' innovation competence. Specifically, for the two cohorts, HLM was conducted using innovative competence as the dependent variable. The independent variables at the student level included gender, socio-economic status, time spent engaging in online gaming, time spent browsing the Internet for information, and the perceived cooperative climate at school. At the school level, the independent variables incorporated were class size and teachers' disruptive behavior.

Lastly, drawing on the method employed by Wong et al. [93], a cross-group comparison was conducted to explore potential

significant differences between children and adolescents regarding the influences of these factors on innovation competence. In this approach, a *t*-test statistic can be computed by dividing the difference between the two unstandardized coefficients by the square root of the sum of squared standard errors:

$$t = \frac{|\gamma_1 - \gamma_2|}{\sqrt{SE_1{}^2 + SE_2{}^2}}.$$

In addition, the effect size (Predictor R^2sp - Squared Semipartial "Part" Correlation) was calculated using Jamovi 2.3.23 to determine the magnitude of influences of these variables on young learners' innovation competence.

4. Results

The results are divided into three sections: descriptive statistics, hierarchical linear modelling, and cross-group comparisons. The descriptive statistics encompass mean values, standard deviations, frequency distributions of variables across both groups, and the Pearson correlations among them, all of which are detailed in Table 4. Drawing from HLM's Intercepts as Outcomes Models, Table 5 delineates the fixed effects and random effects, including the coefficients, standard error (*SE*), Chi-square (χ^2), and significance levels of all variables both at the student and school levels in relation to innovation competence. Lastly, cross-group comparisons were conducted by examining the regression coefficients of the aforementioned variables. The aim was to discern if there were significant disparities between the groups, which is determined based on the calculated *t*-values also presented in Table 5. Furthermore, the effect size was calculated to assess the magnitude of the influences of given variables on innovation competence within the same group, showed in Table 6.

4.1. Results of descriptive statistical analysis

Table 4 presents the means, standard deviations, and Pearson correlation coefficients of variables at the student level, including innovation competence, socio-economic status, perceived cooperative climate at school, and teachers' disruptive behavior for both the 10-year-old and 15-year-old student cohorts assessed in Suzhou. Table 4 also demonstrates the frequency distributions of time spent engaging in online gaming and time spent browsing the Internet for information.

Apart from gender, correlations among innovation competence, socio-economic status, time spent engaging in online gaming, time

Table 4
Descriptive Statistics and Correlation Coefficients.

	Variable	Cohort	Mean (*SD*)/Frequency		Pearson's *r*					
					1	2	3	4	5	6
Student-level variables	1. Innovation competence	10-year-olds	648.66 (92.68)		1[a]					
		15-year-olds	582.11 (68.53)		1[b]					
	2. Socio-Economic Status	10-year-olds	0.34 (0.86)		0.236[a**]	1[a]				
		15-year-olds	0.25 (0.82)		0.187[b**]	1[b]				
	3. Time spent engaging in online gaming	10-year-olds	T = 0 1minute ≤ T ≤ 60 minutes 1 hour < T ≤ 4 hours 4 hours < T	59.4% 30% 7.4% 3.3%	-0.167[a**]	-0.094[a**]	1[a]			
		15-year-olds	T = 0 1 minute ≤ T ≤ 60 minutes 1 hour < T ≤ 4 hours 4 hours < T	52.1% 27.3% 17% 3.5%	-0.136[b**]	-0.145[b**]	1[b]			
	4. Time spent browsing the Internet for information	10-year-olds	T = 0 1 minute ≤ T ≤ 60 minutes 1 hour < T ≤ 4 hours 4 hours < T	45.8% 45.9% 6.6% 1.7%	0.104[a**]	0.069[a**]	0.302[a**]	1[a]		
		15-year-olds	T = 0 1 minute ≤ T ≤ 60 minutes 1 hour < T ≤ 4 hours 4 hours < T	27.8% 63% 8.4% 0.9%	0.098[b**]	0.044[b**]	0.294[b**]	1[b]		
	5. Perceived cooperative climate at school	10-year-olds	2.88 (0.81)		0.504[a**]	0.184[a**]	-0.069[a**]	0.133[a**]	1[a]	
		15-year-olds	2.76 (0.67)		0.41[b**]	0.183[b**]	-0.112[b**]	0.053[b**]	1[b]	
	6. Gender	10-year-olds	-		-0.040[a*]	-0.052[a**]	0.219[a**]	0.083[a**]	-0.008[a] (p = 0.643)	1[a]
		15-year-olds	-		0.065[b**]	-0.019[b] (p = 0.246)	0.296[b**]	-0.001[b] (p = 0.966)	0.028[b] (p = 0.9)	1[b]
School-level variables	Teachers' disruptive behavior	10-year-olds	51.82 (2.78)							
		15-year-olds	51.61 (2.89)							

* *Notes:* [a] = 10-year-old student cohort; [b] = 15-year-old student cohort. $^{**}p < .01$, $^{*}p < .05$. T represents the amount of time spent on the Internet for the corresponding purpose per day. The mean and standard deviation are not presented for gender due to its nominal type.

Table 5
Results of HLM and cross-group comparison.

Fixed effect	Results of intercepts as outcomes model			Cross-group comparison
	γ-coefficient	*SE*	*p*-value	*t* (*p* value)
γ_{00}	663.939[a]/554.261[b]	18.775[a]/5.369[b]	<0.01[a]/< 0.01[b]	–
Gender γ_{10}	−1.543[a]/13.933[b]	2.776[a]/1.872[b]	0.58[a]/< 0.01[b]	4.623 ($p < 0.01$)
Socio-economic Status γ_{20}	15.179[a]/8.046[b]	1.733[a]/1.215[b]	<0.01[a]/< 0.01[b]	3.370 ($p < 0.01$)
Time spent engaging in online gaming γ_{30}	−17.037[a]/-12.971[b]	2.062[a]/1.209[b]	<0.01[a]/< 0.01[b]	1.701 ($p = 0.089$)
Time spent browsing the Internet for information γ_{40}	10.792[a]/13.434[b]	2.152[a]/1.709[b]	<0.01[a]/< 0.01[b]	0.961 ($p = 0.336$)
Perceived cooperative climate at school γ_{50}	48.845[a]/36.772[b]	2.077[a]/2.528[b]	<0.01[a]/< 0.01[b]	3.69 ($p < 0.01$)
Class size γ_{01}	−1.269[a]/0.29[b]	2.367[a]/0.414[b]	0.593[a]/0.486[b]	–
Teachers' disruptive behavior γ_{02}	−2.127[a]/0.252[b]	0.931[a]/0.454[b]	0.025[a]/0.58[b]	2.297 ($p = 0.022$)

Random effect	Variance component	χ^2	*p*-value
τ_{00}	1488.089[a]/334.263[b]	128.167[a]/67.685[b]	<0.01[a]/> 0.50[b]
τ_{11}	99.826[a]/7.827[b]	84.695[a]/64.317[b]	0.186[a]/> 0.50[b]
τ_{22}	34.744[a]/8.165[b]	76.30[a]/49.776[b]	0.404[a]/> 0.50[b]
τ_{33}	74.501[a]/11.129[b]	91.876[a]/58.678[b]	0.078[a]/> 0.50[b]
τ_{44}	61.967[a]/9.235[b]	77.338[a]/60.101[b]	0.372[a]/> 0.50[b]
τ_{55}	115.947[a]/273.458[b]	106.942[a]/168.687[b]	<0.01[a]/< 0.01[b]

* *Note:* [a,b] represent the 10-year-old student cohort and the 15-year-old student cohort, respectively.

Table 6
Summary of the results of hypotheses testing.

Hypotheses	Results	Effect size
H_{1a} Gender has a significant influence on children's innovation competence.	Not Supported	–
H_{1b} Gender has a significant influence on adolescents' innovation competence.	Supported	0.011
H_{1c} The influence of gender on innovation competence differs significantly between children and adolescents.	Supported	–
H_{2a} Children with higher socio-economic status exhibit greater innovation competence.	Supported	0.021 (small)
H_{2b} Adolescents with higher socio-economic status exhibit greater innovation competence.	Supported	0.011
H_{2c} The influence of socio-economic status on innovation competence differs significantly between children and adolescents.	Supported	–
H_{3a} Time spent engaging in online gaming significantly influences the innovative competencies of children.	Supported	0.024 (small)
H_{3b} Time spent engaging in online gaming significantly influences the innovative competencies of adolescents.	Supported	0.021 (small)
H_{3c} There is a significant difference in the influence of time spent engaging in online games on the innovative competencies between children and adolescents.	Not Supported	–
H_{4a} Time spent browsing the Internet for information positively influences children's innovation competence.	Supported	0.007
H_{4b} Time spent browsing the Internet for information positively influences adolescents' innovation competence.	Supported	0.016
H_{4c} There is a significant difference in the influence of time spent browsing the Internet for information on innovative competence between children and adolescents.	Not Supported	–
H_{5a} The perceived cooperative climate at school positively influences the innovative competence of children.	Supported	0.218 (medium)
H_{5b} The perceived cooperative climate at school positively influences the innovative competence of adolescents.	Supported	0.138 (small)
H_{5c} The influence of the perceived cooperative climate at school on innovation competence differs significantly between children and adolescents.	Supported	–
H_{6a} Teachers' disruptive behavior exerts a negative influence on the innovation competence of children.	Supported	0.002
H_{6b} Teachers' disruptive behavior exerts a negative influence on the innovation competence of adolescents.	Not Supported	–
H_{6c} The influence of teachers' disruptive behavior on innovation competence differs significantly between children and adolescents.	Supported	–

**Note:* Effect size: Predictor R^2sp - Squared Semipartial ("Part") Correlation.

spent browsing the Internet for information, and perceived cooperative climate at school were statistically significant for both cohorts, ranging from −0.167 to 0.504 with $p < 0.01$. Additionally, a significant relationship was observed between gender and innovation competence within the 10-year-old student cohort ($r = -0.04$, $p < 0.05$) and the 15-year-old student cohort ($r = 0.065$, $p < 0.01$).

4.2. Results of hierarchical linear modeling

Table 5 presents the findings from the Intercepts as Outcomes Models from the HLM analysis. As illustrated in Table 5, gender did not exhibit a significant influence on the innovation competence of 10-year-old students ($\gamma = -1.543$, $p = 0.58 > 0.05$), suggesting that H_{1a} is not supported. Conversely, gender in the 15-year-old student cohort demonstrated a significant influence on innovation competence ($\gamma = 13.933$, $p < 0.01$), supporting H_{1b}.

For both student cohorts, socio-economic status ([$\gamma = 15.179$, $p < 0.01$], [$\gamma = 8.046$, $p < 0.01$]), time spent browsing the Internet for information ([$\gamma = 10.792$, $p < 0.01$], [$\gamma = 13.434$, $p < 0.01$]), and perceived cooperative climate at school ([$\gamma = 48.845$, $p < 0.01$], [$\gamma =$

36.772, $p < 0.01$]) exhibited significant positive influences on innovation competence. This outcome supports H_{2a}, H_{2b}, H_{4a}, H_{4b}, H_{5a}, and H_{5b}.

A significant negative influence of time spent engaging in online gaming on innovation competence was observed for both cohorts, indicating that Hypotheses 3a and 3b are supported ([$\gamma = -17.037$, $p < 0.01$], [$\gamma = -12.971$, $p < 0.01$]). At the school level, teachers' disruptive behavior had a significant negative influence on the innovation competence of the 10-year-old student cohort ($\gamma = -2.127$, $p = 0.025$), supporting H_{6a}. However, teachers' disruptive behavior did not significantly influence the innovation competence of the 15-year-old student cohort ($\gamma = 0.252$, $p = 0.58 > 0.05$), indicating that H_{6b} is not supported.

4.3. Results of cross-group comparisons

This section investigates whether the influences of variables at the student and school levels on innovation competence differed significantly between the two cohorts. Table 5 displays the outcomes of these cross-group comparisons. The findings indicate that, with the exception of time spent engaging in online gaming and time spent browsing the Internet for information ($t = 1.701$, $p = 0.089$ and $t = 0.961$, $p = 0.336$, respectively), the influences of the other variables on innovation competence exhibited significant differences between the two cohorts (t-values ranging between 2.297 and 4.623, $p < 0.05$). Consequently, all hypotheses, except for Hypotheses 3c and 4c, were supported. Table 6 presents the specific verification of the results for all hypotheses examined in this study.

In addition to comparing the variables' influence on innovation competence across groups, we also used effect size to determine the magnitude of the influences on innovation competence within the same group. Effect sizes are also listed in Table 6. Table 6 shows that socio-economic status and time spent engaging in online gaming have small effects (0.021 and 0.024, respectively), and perceived cooperative climate at school has a medium effect (0.218) for the younger cohort. Among the older cohort, time spent engaging in online gaming and perceived cooperative climate at school have small effects, 0.021 and 0.138 respectively.

5. Discussion

Our analysis determined that student-level factors (socio-economic status, time spent engaging in online gaming, time spent browsing the Internet for information, and the perceived cooperative climate at school) markedly impacted the innovation competence of both children and adolescents. Notably, gender emerged as a significant determinant exclusively for adolescents' innovation competence, while teachers' disruptive behavior at the school level adversely affected only children's innovation competence. Apart from time spent engaging in online gaming and browsing the Internet for information, the influence of all examined variables at both student and school levels on innovation competence demonstrated notable differences between the two age groups. Among the factors analyzed, the perceived cooperative climate at school was identified as having the most substantial effect on innovation competence across both cohorts, underscoring its pivotal role in fostering an environment conducive to innovative thinking and collaboration. The findings of this study are in line the principles SCT, highlighting that individual behavior is influenced by personal attributes, specific behaviors, and environmental factors. In the context of innovation competence in children and adolescents, this includes gender (as a personal attribute), online activities and teacher disruptions (as behaviors), and socio-economic status and school climate (as environmental factors). This illustrates the complexity of developing innovation competence, emphasizing the need to consider a broad range of influences. The following discussion further elaborates on these findings.

5.1. Influences of student-level variables on innovation competence

First, the present study determined that gender did not significantly influence children's innovation competence, but significantly affected adolescents' innovation competence ($\gamma = 13.933$, $p < 0.01$), with males exhibiting greater innovation competence than females during adolescence. This finding is consistent with that of previous research [39,40,54,55] and could be attributed to gender differences in risk preference that emerge during adolescence, with males demonstrating a greater propensity for risk-taking than females [94]. Since risk-taking has been linked to creativity [95], this difference in risk preference might contribute to the higher levels of innovation competence observed among adolescent males as compared to females.

Additionally, the influence of gender on innovation competence differed significantly between children and adolescents, in line with prior research on gender differences in creativity [61,62]. One longitudinal study found that while girls were more creative in childhood and early adolescence, their creative advantage diminished in later adolescence, leading to negligible differences in creativity between genders [62]. The present study found that girls' innovation competence was not significantly higher than that of boys during childhood, but it was significantly lower than that of boys during adolescence – that is, at least from the age of 15. A possible explanation for this difference is that each study used different measurement tools and dimensions.

Second, the current study demonstrated that socio-economic status positively influenced both children's and adolescents' innovation competence ($\gamma = 15.179$, $p < 0.01$, $R^2\text{sp} = 0.021$ and $\gamma = 8.046$, $p < 0.01$, $R^2\text{sp} = 0.011$, respectively) and higher socio-economic status was associated with greater innovation competence. This finding is consistent with that of other research [42,43,63] and could be due to the greater opportunities for exploration and practice provided by higher-socio-economic status families, which could foster the development of innovation competence. Additionally, the current study found that the influence of socio-economic status on innovation competence was significantly higher in children than it was in adolescents, which could be due to the decreasing influence of family and increasing influence of the social environment as children enter adolescence [67–69]. Further confirming this is the fact that the effect of socio-economic status on students' performance in innovation competence diminishes over time.

Third, the study revealed different influences of time spent engaging in online gaming and time spent browsing the Internet for

information on innovation competence in children and adolescents. Time spent engaging in online gaming was found to have a significant negative influence on innovation competence for the two groups ([$\gamma = -17.037$, $p < 0.01$, $R^2\text{sp} = 0.024$] and [$\gamma = -12.971$, $p < 0.01$, $R^2\text{sp} = 0.021$], respectively), in line with the findings of prior research [47,70]. Conversely, time spent browsing the Internet for information was found to have a significant positive influence on innovation competence for the two groups, likely because it fosters the acquisition of updated information, stimulates curiosity, and enhances self-efficacy [75], all of which positively predict creativity [76]. As a result of effect size, time spent engaging in online gaming has a greater negative influence on innovation competence, compared with time spent browsing the Internet for information ($R^2\text{sp} < 0.02$), although this effect size is small for both cohorts. This should cause considerable concern for families, schools, and society. Furthermore, contrary to our initial hypothesis, no significant difference in innovation competence was observed between the two cohorts as a result of the influence of time spent engaging in online gaming or browsing the Internet for information.

Lastly, the current study found that the perceived cooperative climate at school positively influenced innovation competence among children ($\gamma = 48.845$, $p < 0.01$, $R^2\text{sp} = 0.218$) and adolescents ($\gamma = 36.772$, $p < 0.01$, $R^2\text{sp} = 0.138$), which might be due to increased participation in cooperative learning within a positive collaborative school atmosphere, enhancing cooperation among young learners [81,82]. This finding is consistent with the findings of Keinänen et al. [21] which suggest that innovative learning climate is conductive to students' innovation competence. In addition, the effect size of the perceived cooperative climate at school for the younger cohort was close to medium (where a medium effect requires an effect size of greater than or equal to 0.15). For the older cohort, a medium effect size was found. For the two cohorts, this variable had the largest effect compared with other variables. Therefore, we can conclude that a cooperative atmosphere is essential to the development of students' innovative competence. It also aligns with the findings of a large number of scholars who have emphasized the effects of the physical environment on students' ability to innovate [21,25,28,29]. Furthermore, our findings reveal that the influence of the perceived cooperative climate at school on innovation competence differed significantly between children and adolescents, with less influence observed in adolescents than in children. This difference could be attributed to adolescents' increasing independence and self-awareness compared to children [83], which could lead to estrangement from peer influence during adolescence.

5.2. Influences of school-level variables on innovation competence

In addition to class size, a control variable, this study identified a significant negative impact of teachers' disruptive behavior on the innovation competence of younger children ($\gamma = -2.127$, $p < 0.01$). This finding is consistent with existing literature on the impact of such behavior in higher education settings [50,85,86]. Unexpectedly, teachers' disruptive behavior did not significantly affect the innovation competence of adolescents. This discrepancy may be attributed to adolescents' heightened self-awareness and evolved judgment, which may diminish the impact of negative teacher behavior. In addition, as adolescents progress from elementary to higher school levels, they may experience feelings of alienation caused by a lack of trust between adolescents and their teachers [83], which may mitigate or even negate the impact of disruptive teacher behavior on their innovation competence.

Our analysis also revealed that the negative impact of teachers' disruptive behavior on innovation competence is more pronounced in children than in adolescents. Given the critical role teachers play in shaping initial school experiences, their disruptive behavior can significantly undermine young children's ability to innovate. The diminished effect observed in adolescents could stem from a general decrease in teacher influence as students mature [83], rendering such behavior less impactful on their innovation competence.

While this research primarily explores how various factors influence innovation competence among 10 and 15-year-olds, including the differences in effects between these groups, it is important to note that innovation competence profiles can also be shaped by personal traits like resilience and self-monitoring [96]. Therefore, a future research direction could involve a person-centered approach to investigating innovation competence, offering a nuanced understanding of its development across individual profiles.

6. Implications

This study explores the determinants of innovation competence among children and adolescents, employing a SCT framework to examine the impact of individual, familial, and educational factors. Additionally, the research probes whether these influences exhibit significant variations across the two age cohorts. The implications of these findings are multiple. First, a significant gender disparity in adolescents' innovation competence should remind parents and educators to respect gender differences and teach students according to their aptitude in the training of adolescents' innovation competence. Second, the dual influence of online gaming and internet browsing for information on innovation competence—detrimental in the case of online gaming and beneficial for information searching—calls for vigilant monitoring and guidance by parents and educators in internet usage among students. The study advocates for restricted exposure to online gaming in childhood and the adoption of strategies to prevent addiction.

Furthermore, the perceived cooperative climate at school and teachers' disruptive behavior significantly affected the innovation competence of both children and adolescents, with the school climate exerting the most substantial influence among the examined variables. It is imperative for educational institutions to cultivate a positive and collaborative learning environment. Addressing teacher-induced disruptions, particularly in primary education, is crucial due to their adverse effects on student innovation competence.

Through the lens of SCT, this research demonstrates that innovation competence is a complex construct influenced by an interplay of personal characteristics, behaviors, and environmental contexts. SCT provides a comprehensive framework for exploring additional factors that may influence the development of innovation competence in children and adolescents throughout their educational journey, including personality traits, pedagogical approaches, and parenting styles.

7. Limitations

While this study provides insightful observations on the determinants of innovation competence in children and adolescents through the lens of SCT, and presents an intriguing analytical framework, it is not without its limitations. Firstly, the adoption of a cross-sectional study design restricts the ability to discern temporal patterns in how influencing factors may shape innovation competence over time. This highlights the necessity for future investigations to embrace longitudinal methodologies to bridge this methodological gap. Secondly, the focus on specific age cohorts, namely 10- and 15-year-olds, while informative, introduces certain constraints. Notably, the analysis does not extend to a comprehensive delineation of the four dimensions of innovation competence, nor does it offer a nuanced model that accounts for the diversity in participant profiles. Addressing these complexities through latent profile analysis is suggested as a promising avenue for subsequent research endeavors.

Lastly, this study serves as an initial exploration of the factors influencing innovation competence, despite identifying some contributing factors. A significant limitation, however, lies in our use of secondary data, which restricts the scope of our analysis to the variables already included in the dataset, leaving other potentially relevant factors unexamined. Future research should utilize broader datasets to thoroughly investigate the diverse factors impacting youth innovation competencies, enabling a deeper, more focused analysis.

Ethics statement

The study was conducted using publicly available secondary data obtained from the OECD's Survey on Social and Emotional Skills (SSES). As this research involves the analysis of pre-existing, publicly available data and does not involve any new data collection or interaction with human participants, it was exempt from requiring a separate ethical approval from the authors' institutional review board, as confirmed by the Institutional Review Board of the Jiangxi Psychological Consultant Association. All data used in this study was anonymized, and no personal identifiable information was accessed or used by the authors.

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Data availability statement

The data that supports these findings of this study are openly available data from SSES. The data was retrieved from the following website:
https://www.oecd.org/education/ceri/social-emotional-skills-study/data.htm.

CRediT authorship contribution statement

Xiu-Mei Chen: Writing – original draft, Data curation, Conceptualization. **I-Hua Chen:** Writing – review & editing, Methodology, Conceptualization. **Xing-Yong Jiang:** Writing – review & editing, Visualization, Software. **Xu-Dong Li:** Writing – review & editing, Validation. **Jeffrey Hugh Gamble:** Writing – review & editing, Visualization, Supervision.

Declaration of competing interest

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Appendix

Table S1
Items of construct

Construct	Item ID	Items
Creativity	STA_CRE01	I find new ways to do things.
	STA_CRE02	I am original, and come up with new ideas.

(*continued on next page*)

Table S1 (*continued*)

Construct	Item ID	Items
	STA_CRE04	I sometimes find a solution other people don't see.
	STA_CRE05	I like to create things.
	STA_CRE06	I have a good imagination.
	STA_CRE07	I find it difficult to create new things.
Curiosity	STA_CUR02	I am eager to learn.
	STA_CUR04	I like to know how things work.
	STA_CUR05	I like learning new things.
	STA_CUR06	I don't like learning.
	STA_CUR07	I love learning new things in school.
	STA_CUR08	I find science interesting.
Cooperation	STA_COO01	I like to help others.
	STA_COO02	I get along well with others.
	STA_COO03	I work well with other people.
	STA_COO04	I start arguments with others.
	STA_COO06	I am always willing to help my classmates.
	STA_COO07	I am ready to help anybody.
	STA_COO08	I am polite, courteous to others.
Responsibility	STA_RES01	I sometimes behave irresponsibly.
	STA_RES03	I often forget my duties.
	STA_RES04	I avoid responsibilities.
	STA_RES05	I keep my promises.
	STA_RES06	I am a responsible person.
	STA_RES08	I forget to do work I was asked to do.
Time spent engaging in online games	STQM03606	During a typical weekday, how much time do you spend playing online games?
Time spent browsing the Internet for information	STQM03610	During a typical weekday, how much time do you spend browsing the Internet for information (e.g., reading news or looking up locations)?
Perceived cooperative climate at school	STQM03801	Students seem to value cooperation (e.g., working together).
	STQM03802	It seems that students cooperate with each other.
Teachers' disruptive behavior	PRQM02701	Teachers do not meet individual students' needs.
	PRQM02702	Teacher absenteeism.
	PRQM02703	Staff resist change.
	PRQM02704	Teachers are too strict with students.
	PRQM02705	Teachers are late to classes.
	PRQM02706	Teachers are not well-prepared for classes.
Class size	PRQM00601	What is the average size of classes in your school?

*_Note:_ All the above-mentioned English codes were taken from the Survey on Social and Emotional Skills Technical Report [35].

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