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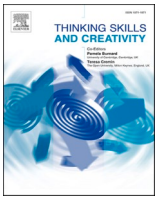

Survey on the influential demographic factors of Chinese undergraduate students' critical thinking disposition: Evidence from plausible values

Yong Liu [a,*], Attila Pásztor [b,c,d]

[a] Doctoral School of Education, University of Szeged, Hungary
[b] Institute of Education, University of Szeged, Hungary
[c] MTA-SZTE Research Group on the Development of Competencies, Hungary
[d] MTA-SZTE Digital Learning Technologies Research Group, Hungary

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ABSTRACT

Critical thinking disposition (CTD), the facet of critical thinking, regarded as the basis to activate critical thinking skills, is the inclination to think critically. Previous studies on the factors influencing CTD in undergraduate students yielded inconsistent results, often examining these factors based on raw scores without considering plausible values (PVs) which can unbiasedly provide estimates that are closer to the truth. This study aims to explore the factors (e.g., gender, year of study, major, parents' educational level, family income, residence, and type of university) that potentially influence undergraduate students' CTD using PVs. This study involved 661 Chinese undergraduate students (female students represented 50.4%), utilizing the Employer–Employee–Supported Critical Thinking Disposition Inventory for data collection. After calculating PVs using item response theory, linear regression models through dummy variable regression on the PVs were conducted. The findings revealed that when the factors were examined individually, CTD may vary by type of university, year of study, parents' educational level, and family income. However, when the factors were integrated into a comprehensive robust regression model, family income was identified as the unique factor influencing CTD, indicating that individuals from higher-income families exhibited higher CTD levels than students from lower-income families. Demographic factors accounted for 5%–10% of the variation. Future research should investigate additional factors that may substantially impact on college students' CTD. It is crucial for educators to acknowledge the disparities in CTD prevalence based on family income and devise an effective way to promote CTD among individuals from low-income backgrounds.

1. Introduction

The concept of critical thinking (CT) is inconsistent because of its complexity, which can date back to Ancient Greece. With its evolvement, a comprehensive modern CT definition can be integrated into the deliberate and self-regulating judgment that resulted in interpretation, analysis, evaluation, and inference, as well as an explanation of the evidentiary, conceptual, methodological,

* Corresponding author.
E-mail address: yongl0513@gmail.com (Y. Liu).

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criteriological, or contextual factors that underpinned that judgment (Facione, 1990). Based on the abstract concept, a two-dimensional CT framework with critical thinking skills (CTS) and critical thinking disposition (CTD) was established from the original one-dimensionality including only CTS. CTS, the competence-focused facet, generally comprises of the skills for interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 1990). While CTD, the motivational and attitudinal facet of CT, is often regarded as the activation of CTS and the basis of CT (Valenzuela et al., 2011).

In addition, CT can be cultivated and improved via certain teaching methods, especially the problem-based learning (Liu & Pásztor, 2022b), which requires instructors to pay more attention to the influencing factors of its effectiveness. Accordingly, Liu and Pásztor (2022a) extended the CT framework from the two dimensions of CTS and CTD to a comprehensive framework with CTD and CTS as the conceptual inputs and scenario problem-solving as the practical output (Liu & Pásztor, 2022a). This construct integrates effective instructional interventions to help students develop motivational disposition, mastery skills, and problem-solving skills. Although CTD and CTS, as the inputs, are both vital to solve problems, CTD is regarded as the basis of CTS, and, thus, CTS cannot be achieved without sufficient CTD (Valenzuela et al., 2011). Nevertheless, the level of CTD may be influenced by many factors which could affect the efficacy of CT interventions and development. Previous studies investigating the factors influencing CTD in undergraduate students yielded inconsistent results, often examining these factors based on raw scores without considering plausible values (PVs). Thus, this study explores the potentially influential factors (e.g., gender, year of study, major, parents' educational level, family income, residence, and type of university) on undergraduate students' CTD using PVs.

2. Literature review

2.1. CTD concept and framework

CTD, required for activating CTS, is a form of consolidated intellectual habit comprising the traits of inclination, propensity, tendency, and willingness to think critically (Ennis, 2011; Norris, 2003; Paul & Binker, 1990; Perkins et al., 1993; Salomon, 1994). Different frameworks are found in the literature; however, one of the most influential is derived from the California Critical Thinking Disposition Inventory (CCTDI; Facione & Facione, 1992) which was inspired and summarized by the Delphi Report (Facione, 1990).

The CCTDI comprises seven elements: analyticity, inquisitiveness, systematicity, open-mindedness, truth-seeking, self-confidence, and maturity. However, due to the problems of the reliability and validity in previous studies, in both the original and adapted versions, the unified and shortened test versions were recommended (Liu & Pásztor, 2022a; Walsh & Hardy, 1997; Walsh et al., 2007). Yoon (2004) renamed the framework of CCTDI and shortened it to 27 items belonging to seven factors: intellectual curiosity, systematicity, prudence, objectivity, self-confidence, healthy skepticism, and intellectual fairness. Though acceptable reliability and validity were obtained, the factors still overlapped. Sosu (2013) adopted the suggestions from previous studies to shorten and unify the seven factors into two dimensions (critical openness and reflective skepticism) with 11 items in total, whereas the model fit of a one-factor model seemed better than the two-factor model (Bravo et al., 2020; Yockey, 2016). Quinn et al. (2020) developed their framework based on the literature and through consulting instructors and students. They suggested six subscales: open-mindedness, reflection, attentiveness, organization, intrinsic goal motivation, and perseverance. However, the reliability of each dimension of the assessment tool was not acceptable in all cases, with values ranging from 0.59 to 0.82. Furthermore, certain dimensions may still be conceptually vague. Liu and Pásztor (2022a), inspired by Quinn et al. (2020), built a CTD framework with 19 items distributed in three dimensions (instant judgment, self-efficacy, and habitual truth-digging) from the perspectives of literature, experts, employers, and employees, which avoided the problem of overlapping concepts. Despite there being no additional validation studies for cross-national validity, due to its novelty, the acceptable reliability and validity of both classical and probabilistic test theories proved they were dependable (Liu & Pásztor, 2022a).

2.2. Influencing factors of previous studies on undergraduate students' CTD

The most frequently examined influencing factor on CTD in undergraduate students is gender, and participants involved in studies are medical students. However, the results are inconsistent. Other demographic factors were also explored.

For the single-factor variance analysis studies, Gezer et al. (2017) found no difference among nurses' ages, years of training, incomes, or educational levels via the CCTDI. Using Ricketts' critical thinking disposition questionnaire (Ricketts, 2003) with innovation, engagement, and maturity as subdimensions, no difference was identified across gender and marital status, but the statistical difference was found among year of study and interest in major in nursing students (Mousazadeh et al., 2021). Boonsathirakul and Kerdsomboon (2021) found no difference in gender and year of study via an adapted CCTDI. Similar results from Liu et al. (2019) demonstrated that no gender or age differences among nursing students.

However, the study by Park (2019) on nursing students via a self-developed scale found a gender difference in undergraduate students' CTD (Yeun et al., 2005). Yenice (2011) also identified a gender difference, although there was no difference by year of study level in preservice science teacher students. Walsh and Hardy (1999) found differences by gender in open-mindedness and maturity but not for overall CTD; additionally, there was a difference among majors, and nursing students performed better. Furthermore, a thorough meta-analysis by Liu and Pásztor (2022b) investigated the influence of gender, year of study, and major separately on CTD, and found no gender or year of study difference, while students in the Arts performed better than medical and science students.

For the multivariate regression and structural equation modeling studies, Wang et al. (2019) performed a regression analysis by gender, age, and major, and found they significantly predicted CTD in medical undergraduate students, but only on some subdimension, such as open-mindedness, systematicity, and truth-digging. Zhang et al. (2010) conducted a regression analysis on the

influence of gender, year of study, major, family information, census register, and another ten factors, finding that the basic five elements were unrelated to medicine and nursing students' CTD. Karahan and Iskifoglu (2020) conducted a prediction analysis of most demographic factors, concluding that mothers' educational level was predictive while age and fathers' educational level explained the smallest variance and family social level showed no influence among more than 1000 students from different majors. Huang et al. (2019) analyzed the influence of family socioeconomic status (SES) on medical undergraduate students' CTD finding that students from higher SES may have stronger CTD.

3. The research aims and questions

To summarize, the previous studies identified different results regarding the influencing factors of CTD based on the means of the raw scores without considering PVs. Thus, this study aims to explore the factors (gender, year of study, major, parents' educational level, family income, residence, and type of university) of potential influence on undergraduate students' CTD using PVs. The research questions are as follows:

Research question 1: Are there statistical differences among subdimensions of each factor separately?
Research question 2: What factors influence undergraduate students' CTD in a multivariate linear regression model?
Research question 3: Are the results different between basic difference analysis and regression analysis?

Table 1
The sample's demographic information.

Demographic Variables	Sub-category	N	Percentage (%)	Age Mean ± SD
Gender	Boy	328	49.6	19.22 ± 1.21
	Girl	333	50.4	19.91 ± 1.24
Major	Humanity, Arts, & Social Sciences	274	41.5	20.02 ± 1.26
	Natural Sciences	387	58.5	19.24 ± 1.16
Year of Study[a]	Vocational 1	108	16.3	18.77 ± 1.04
	Vocational 2	21	3.2	19.76 ± 0.83
	Vocational 3	30	4.5	20.53 ± 1.80
	Bachelor 1	149	22.5	18.66 ± 0.91
	Bachelor 2	196	29.7	19.66 ± 0.82
	Bachelor 3	138	20.9	20.58 ± 0.87
	Bachelor 4	19	2.9	21.14 ± 1.91
University Property	Public	183	27.7	19.74 ± 1.43
	Private	478	72.3	19.50 ± 1.19
Residence Property[b]	Urban	222	33.6	19.56 ± 1.27
	Rural	439	66.4	19.58 ± 1.25
Father's Educational Level	Below Primary School	5	0.8	19.60 ± 0.89
	Primary School	185	28.0	19.68 ± 1.41
	Junior Secondary School	277	41.9	19.52 ± 1.18
	Senior Secondary School	94	14.2	19.49 ± 1.37
	Vocational University	57	8.6	19.42 ± 1.10
	Bachelor	33	5.0	19.68 ± 1.13
	Master	4	0.6	20.00 ± 0.82
	Doctor	6	0.9	20.00 ± 1.26
Mother's Educational Level	Below Primary School	23	3.5	19.43 ± 1.20
	Primary School	257	38.9	19.68 ± 1.33
	Junior Secondary School	239	36.2	19.51 ± 1.24
	Senior Secondary School	72	10.9	19.33 ± 1.10
	Vocational University	37	5.6	19.51 ± 1.43
	Bachelor	22	3.3	19.62 ± 1.05
	Master	6	0.9	20.00 ± 0.63
	Doctor	5	0.8	20.00 ± 1.41
Family Income[c] (USD)	0 – 12,000	436	66.0	19.50 ± 1.26
	12,000 – 28,000	184	27.8	19.70 ± 1.25
	28,000 – 280,000	32	4.8	19.72 ± 1.33
	> 280,000	9	1.4	19.51 ± 1.11

Note:
[a] Vocational level and bachelor level both belong to the university level in China.
[b] Residence property is the registered permanent residence of the students.
[c] Family income is the income of all members in a family per year excluding the tax, the cutoff of which is based on the 2022 Wealth Report of China (Ren, 2022): 12,000 is the average, 28,000 belongs to a well-to-do family, 280,000 will be the fairly well-off, and more than 280,000 is the rich level. The currency is 1 USD = 7.14 CNY.

4. Methods

4.1. Research design

This is a self-reported survey study in which formal agreement was received from both the research committee and the students. Following the recruitment of undergraduate students, an online survey platform was used to collect data using a 7-point Likert scale with some demographic information items. After the re-coding of the raw scores of certain reversed questions, the instrument's reliability and validity were evaluated, and plausible values were created from the raw scores for further study based on the dependable measurement tool.

4.2. Participants

The participants in this study are 661 Chinese undergraduate students. To recruit college students for this study, student counsellors from four universities were invited to assist in distributing online questionnaires to their respective student populations. Furthermore, participating students were encouraged to further share the questionnaire with other undergraduate students whom they were acquainted with. Recruitment was managed and overseen by the university coordinators. All information is confidential and used only for research purposes. Ethical approvals were obtained from both the university research committee and university administrators. The detailed demographic information is listed in Table 1 below.

4.3. Instrument

The assessment tool used in this study is the Employer–Employee–Supported Critical Thinking Disposition Inventory (2ES–CTDI), which has been validated by Liu and Pásztor (2022a), confirming its reliability, content validity, and construct validity. It is a seven-point Likert scale from strongly disagree to strongly agree consisting of three kinds of dispositions of CT: instant judgment (three items), self-efficacy (five items), and habitual truth-digging (11 items). Similar to the competitive procedure concluded by Kahneman (2011) on fast and slow thinking in the human mind, instant judgment, and habitual truth-digging perform the same tendency in this study, balancing between judging quickly and accurately versus analyzing methodically, with the mediation of self-efficacy (Liu & Pásztor, 2022a; 2023). The overall CTD is measured by integrating all these three dimensions.

The validation process begins with a check on factor loadings and the scale's dependability on each item and factor. This study's reliability was determined using Cronbach's Alpha value (> 0.7; Cronbach, 1951). Confirmatory factor analysis was applied to test the overall model fit based on the Structural Equation Modelling technique. The referred values and cutoffs are: the Chi-square (Pearson, 1900) and the Chi-square/*df* should be below 5; the Root Mean Square Error of Approximation (RMSEA; Steiger, 1990) and the Standardized Root Mean Square Residual (SRMR; Bentler, 1995) should be less than 0.08 (Hu & Bentler, 1999); the Comparative Fit Index (CFI; Bentler, 1990) and the Tucker–Lewis index (TLI; Bentler & Bonett, 1980; Tucker & Lewis, 1973) should be around or more than 0.09. According to the cutoffs mentioned above, the reliability and structure validity of this instrument are acceptable for further analysis with the significance of factor loadings of all items, Cronbach's Alpha $= 0.826$, $\chi^2/df < 5$, CFI $= 0.935$, TLI $= 0.925$, RMSEA $= 0.044$, SRMR $= 0.048$.

4.4. Data analysis procedure and techniques

The data analysis procedure was conducted in two formal steps: the computation of PVs based on item response theory via ConQuest version 2.0 (Wu et al., 2007) and the robust linear regression model construction via Stata/SE version 17.0 (StataCorp, 2021). However, the prerequisite for including categorical variables in the regression model is coding them into dummy variables. The

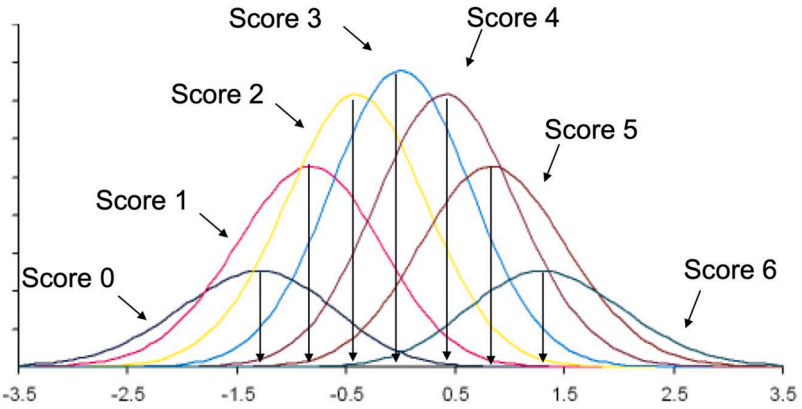
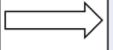


Fig. 1. The distribution of students' proficiency in a six-item test (Wu, 2004).

Student ID	Father's Education Level
1	Below Primary School
2	Primary School
3	Junior Secondary School
4	Senior Secondary School
5	Vocational University
6	Bachelor
7	Master
8	Doctor



Student ID	Below Primary School	Primary School	Junior Secondary School	Senior Secondary School	Vocational University	Bachelor	Master	Doctor
1	1	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0
4	0	0	0	1	0	0	0	0
5	0	0	0	0	1	0	0	0
6	0	0	0	0	0	1	0	0
7	0	0	0	0	0	0	1	0
8	0	0	0	0	0	0	0	1

Fig. 2. The sample of dummy variables conversion of father's education level.

t-test and analysis of variance (ANOVA) were adopted to explore the basic difference within each variable instead of mutual interactions together in the regression model before further analysis following PV generation.

Unlike traditional achievement raw scores observed directly, PVs can achieve further imputation of students' latent ability, when used appropriately, providing unbiased estimates. It has been concluded that the traditional Maximum Likelihood Estimate (MLE) and the Expected A-Posteriori estimate (EAP) used in studies do not recover variance correctly (Wu, 2004). PVs have been used in many large-scale assessments such as the National Assessment of Educational Progress surveys, the Trends in International Mathematics and Science Study, and the Program for International Student Assessment. PVs are not the discrete and fixed points of a student's ability level but rather are randomly drawn from the probability distributions of students' ability. For example, Fig. 1 shows the proficiency distribution of students in a six-item test scored from 0 to 6, in which the black vertical lines represent the EAP estimates. If a proficiency level above 1.0 is chosen, based on EAP, they will obtain a score of six, while for PVs, they are most likely to achieve a score of six, and can also have the possibility of scoring three, four, or five. Thus, although the random values are drawn from the distribution, using PVs is still more effective than the traditional methods at avoiding estimation bias.

After the generation of PVs that are established as the dependent variables, the *t*-test and ANOVA will be conducted to verify the difference among each subdimension in each factor separately, providing an overview of the variance. The regression analysis will then be carried out considering all variables' interactions. However, all categorical independent variables should be coded into dummy variables in case they can be estimated in the regression model. Dummy coding, the most common and convenient coding method, switches multi-categorical variables into dichotomous ones which are only valued at zero and one. Although the education level is an ordinal variable in some studies, the distance between each level may differ. Thus, this study treats it as a categorical variable. For example, the father's education level is a categorical variable with eight subdimensions. The number of dummy variables created should be $k-1$ to avoid collinearity, in which, k is the total subdimensions. However, this study will use the Stata software to do the regression analysis. Stata can generate dummy variables automatically and omit the collinear one as the control variable. Thus, the father's education level can be converted into eight dummy variables shown in Fig. 2, in which, the controlled variable for each factor can be randomly selected or manually selected by the software. The other categorical variables will also be coded in the same way.

Nevertheless, it is important to note that with the inclusion of dummy variables, the robustness of the model will be degraded if the sample has observations with anomalies (Blankmeyer, 2006). However, the outliers should not be deleted because they may have some indications for the results. The robust regression will not discard these anomalies but rather treats them as residuals. The basic linear regression analysis considers the equivariance, which may cause high-breakdown points (Seheult et al., 1989). Thus, robust linear regression analysis will be adopted to keep the model stable without the big influence from outliers.

The common selection methods of independent variables are forward, backward, and stepwise, in which the first two methods only use one direction ignoring the influence of some variables. Thus, this study will adopt the stepwise method (Cramer & Bock, 1966) that adds independent variables one by one, deleting those that are insignificant after addition. Nevertheless, the order of addition will also influence the model. Because there are many variables, this study cannot consider all the options in the order of addition. Therefore, the full model with all potential independent variables will be checked first. Based on the level of significance, the most significant one will be selected as the starting point, and other independent variables will be added in order. In this procedure, insignificant added or previous variables are deleted.

5. Results

5.1. Differences among subdimensions of each demographic factor separately

Based on PVs, the *t*-test and ANOVA results (as shown in Tables 2 and 3, respectively) indicated (a) no difference between male and female students ($t = -1.243$, $p > .05$); (b) no difference was found for students majoring in Arts ($M = 0.26$, SD = 0.46) and Sciences ($M = 0.20$, SD = 0.48; $t = 1.41$, $p > .05$), and for students who reside in cities ($M = 0.27$, SD = 0.48) and rural areas ($M = 0.20$, SD = 0.47; $t = -1.87$, $p > .05$). (c) However, students of public universities ($M = 0.30$, SD = 0.58) showed higher CTD than those at private universities ($M = 0.20$, SD = 0.42; $t = 2.45$, $p < .05$); (d) there was a significant difference among fathers' educational levels ($F_{(7, 653)} = 2.09$, $p < .05$). Based on post hoc Tukey's b, the CTD of students whose fathers have a doctoral degree ($M = 0.80$, SD = 0.82) is higher than others; and (e) a difference was found among students based on mothers' educational levels ($F_{(7, 653)} = 4.89$, $p < .001$). According to the post hoc Dunnett T3, the CTD of the students whose mothers had vocational degrees ($M = 0.50$, SD = 0.55) was found to be

Table 2
The T-Test difference of individual and institutional variables.

Category	Sub-dimension	N	Mean ± SD	*t-test*		
				t	*df*	*p*
Gender	Boy	328	0.20 ± 0.51	−1.24	659	> 0.05
	Girl	333	0.25 ± 0.43			
Type of University	Public	183	0.30 ± 0.58	2.12	257.04	< 0.05
	Private	478	0.20 ± 0.42			
Major	Humanity, Arts, & Social Sciences	274	0.26 ± 0.46	1.41	659	> 0.05
	Natural Sciences	387	0.20 ± 0.48			
Residence Property	Rural	439	0.20 ± 0.47	−1.87	659	> 0.05
	Urban	222	0.27 ± 0.48			

Table 3
The ANOVA difference of individual and institutional variables.

Category	Sub-dimension	N	Mean ± SD	ANOVA F	*df-between-group*	*df-within-group*	*p*	Homogeneity p-value
Year of study	V1	108	0.21 ± 0.53	2.59	6	654	< 0.05	< 0.001
	V2	21	0.25 ± 0.84					
	V3	30	0.10 ± 0.45					
	B1	149	0.19 ± 0.40					
	B2	196	0.20 ± 0.43					
	B3	138	0.29 ± 0.43					
	B4	19	0.54 ± 0.73					
Father's Educational Level	BPS	5	0.16 ± 0.26	2.90	7	653	< 0.05	> 0.05
	PS	185	0.23 ± 0.48					
	JSS	277	0.23 ± 0.45					
	SSS	94	0.21 ± 0.44					
	VU	57	0.26 ± 0.47					
	Bachelor	33	0.12 ± 0.51					
	Master	4	−0.21 ± 0.49					
	Doctor	6	0.80 ± 0.82					
Mother's Educational Level	BPS	23	0.14 ± 0.27	4.89	7	653	< 0.001	< 0.05
	PS	257	0.22 ± 0.43					
	JSS	239	0.19 ± 0.47					
	SSS	72	0.23 ± 0.43					
	VU	37	0.50 ± 0.55					
	Bachelor	22	0.23 ± 0.71					
	Master	6	−0.24 ± 0.33					
	Doctor	5	0.96 ± 0.91					
Family Income (USD)	0 – 12,000	436	0.19 ± 0.43	10.59	3	657	< 0.001	< 0.05
	12,000 – 28,000	184	0.29 ± 0.52					
	28,000 – 280,000	32	0.15 ± 0.44					
	> 280,000	9	1.00 ± 0.64					

Note: BPS = Below Primary School; PS = Primary School; JSS = Junior Secondary School; SSS = Senior Secondary School; VU = Vocational University; V1-V3 = Vocational 1 to 3; B1-B4 = Bachelor 1 to 4.

higher than that of those whose education was at the level of primary school ($M = 0.14$, SD = 0.27) or who had a master's degree ($M = -0.24$, SD = 0.33); however, the mean of those with a Ph.D. ($M = 0.96$, SD = 0.81) was the highest. Additionally, (f) a significant difference was found in family income ($F_{(3, 657)} = 10.59$, $p < .001$). Accordingly, the post hoc Dunnett T3 showed that the CTD of students from families whose income was 280,000 dollars per year ($M = 1.00$, SD = 0.64) was higher than those whose family income was less than 12,000 dollars per year ($M = 0.19$, SD = 0.43) or that was in the 28,000 to 280,000 dollars per year range ($M = 0.15$, SD = 0.44). (g) An evident difference was identified between the last-year undergraduate students and those in other grades as a whole cohort ($F_{(6, 654)} = 2.586$, $p < .05$). However, the post hoc Dunnett T3 did not identify the difference, which may be caused by the significance level of ANOVA being quite close to 0.05. Thus, basically, there was no difference found among year of study.

5.2. Robust linear regression model results

This study tested nine robust linear regression models listed in Table 4, and all nine models can be identified with significant F test results. The first model is the full model with all the independent variables, which showed that the family income and type of university significantly influenced students' CTD with the significance of some dummy variables in each factor, in which, the CTD of students from the family with the income of more than 280,000 was the strongest with no difference from 12,000 to 28,000 family, and others were nearly the same. Students in public universities seemed to have a higher CTD than private university students, and other factors did not witness significant effects.

Based on the significance level, the second is the starting point with the family income only, indicating that the CTD of students whose families had an income of 12,000 to 28,000 was significantly lower than students of families whose income was greater than 280,000, its distance from the highest was the shortest, and the trends of other dummy variables were same at that of the model. The type of university, which was significant in the full model, when added to the third model together with the family income, was not influenced by the type of university and family income similarly to the second model. Then, the type of university was deleted and the father's educational level was added to the fourth model with the family income. No difference was identified in students' CTD among the father's education level, and the family income results were like the previous outcomes.

The fifth model deleted the father's educational level and added the mother's educational level and the family income. The impact of family income was the same as in model one, but the mother's educational level did have a greater influence on students' CTD. The CTD of students whose mothers had attained a doctoral degree was much higher than that of students whose mothers had a master's degree. Regarding the significance of the mother's educational level, the sixth, seventh, and eighth models all kept this variable together with family income and added and deleted the residence, major, and year of study, respectively, because of their insignificance in the models. However, the results of family income were nearly similar to previous models. The difference was that the mother's educational level significantly affected students' CTD in models six and seven with the same trend as in model five, while it

Table 4
The stepwise robust linear regression models.

Independent Variables	Dummy Variables	Coefficients in Different Regression Models 1	2	3	4	5	6	7	8	9
Family Income (USD)	0 – 12,000	−0.593*	−0.807***	−0.783***	−0.728**	−0.624*	−0.618*	−0.624*	−0.638*	−0.82***
	12,000 – 28,000	−0.518	−0.711**	−0.691**	−0.620*	−0.538	−0.537	−0.540	−0.568*	−0.72***
	28,000 – 280,000	−0.595*	−0.849***	−0.825***	−0.720**	−0.668*	−0.671*	−0.663*	−0.684*	−0.86***
	> 280,000	0	0	0	0	0	0	0	0	0
Type of University	Public	.098*		.081						
	Private	0		0						
Father's Educational Level	BPS	0			0					
	PS	−0.011			.042					
	JSS	−0.033			.037					
	SSS	−0.108			.013					
	VU	−0.174			.028					
	Bachelor	−0.241			−0.093					
	Master	−0.155			−0.396					
	Doctor	.131			.260					
Mother's Educational Level	BPS	−0.195				−0.456	−0.443	−0.464	−0.316	
	PS	−0.112				−0.389	−0.375	−0.402	−0.245	
	JSS	−0.146				−0.429	−0.418	−0.440	−0.283	
	SSS	−0.058				−0.389	−0.384	−0.398	−0.238	
	VU	.198				−0.164	−0.163	−0.169	−0.013	
	Bachelor	−0.030				−0.425	−0.427	−0.438	−0.271	
	Master	−0.538				−0.861*	−0.856*	−0.868*	−0.689	
	Doctor	0				0	0	0	0	
Residence Property	Rural	−0.043					−0.029			
	Urban	0					0			
Major	HASS	.012						.058		
	NS	0						0		
Year of Study	V1	−0.015							−0.230	
	V2	0							−0.185	
	V3	−0.159							−0.319	
	B1	.001							−0.233	
	B2	−0.002							−0.226	
	B3	.092							−0.133	
	B4	.169							0	
Gender	Boy	−0.001								−0.056
	Girl	0								0
Constant		.936*	.997***	.951***	.886**	1.214***	1.220***	1.202***	1.293***	1.040***
F		2.83***	6.87***	5.81***	2.79**	3.97***	3.66***	4.03***	2.96***	5.73***
R^2		.109	.046	.052	.056	.075	.075	.078	.089	.050
Root MSE		.454	.461	.460	.461	.457	.457	.456	.456	.461

Note: $N = 661$; the variable with the value of 0 represents the controlled variable in each factor; Root MSE = Root-Mean-Square Error; BPS = Below Primary School; PS = Primary School; JSS = Junior Secondary School; SSS = Senior Secondary School; VU = Vocational University; HASS = Humanity, Arts, & Social Sciences; NS = Natural Sciences; V1-V3 = Vocational 1 to 3; B1-B4 = Bachelor 1 to 4; *$p < .05$; **$p < .01$; ***$p < .001$.

was not significant in model eight. Thus, the mother's educational level was deleted from model nine while gender and family income were together added to the model. Still, no significance was found for gender and the results of the impact of family income were the same as in model one. Therefore, it is recommended that gender be removed from the final model.

In conclusion, after adding and deleting variables based on the significance level, the final model had only family income as the independent variable, the same as the second model. The general results were similar to those of ANOVA on family income. While this regression analysis adopted a robust method, the difference among each dummy variable of family income needed to be explored based on the robust results. The regression equation is as follows:

Table 5
The means and difference of CTD among subdimensions in family income.

CTD Means & F-Test		0 – 12,000 .190	12,000 – 28,000 .286	28,000 – 280,000 .148	> 280,000 .997
0 – 12,000	.190	–			
12,000 – 28,000	.286	4.78*	–		
28,000 – 280,000	.148	0.29	2.63	–	
> 280,000	.997	15.82***	11.99***	15.52***	–

Note: *$p < .05$; ***$p < .001$.

$$Y = b + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \varepsilon \quad (1)$$

In Eq. (1), beta represents the coefficient, x stands for dummy variables, b is the constant, Y is the CTD plausible value, and ε is the random error. For example, in the built model of this study, x_1 represents family income of 0 to 12,000, and so forth. Thus, the regression model identified in this study is constructed as follows in Eq. (2):

$$Y = .997 - .807 * x_1 - .711 * x_2 - .849 * x_3 + 0 * x_4 + \varepsilon \quad (2)$$

Based on Eq. (2), the mean of each dummy variable can be calculated, and the difference between every two of them can be tested presented in Table 5. For example, when x_4 equals 1 for those whose family income is more than 280,000, x_1, x_2, and x_3 are 0, and the mean CTD of those whose family income is more than 280,000 is 0.997. Thus, the results from the robust analysis showed that the CTD level of students from families whose income is greater than 280,000 was far higher than that of students from families with other income levels. In addition, a small difference was observed: the CTD of students from families whose income was between 12,000 and 28,000 seemed slightly higher than those whose family income ranged from 0 to 12,000.

5.3. Comparison between basic difference analysis and regression analysis

Based on the comparison, the *p-values* in ANOVA of the type of university, year of study, and father's educational level, despite the existence of difference, were almost 0.05, indicating only a marginal difference and if the study adopts the stricter cutoff, they may be insignificant. In contrast, the *p-values* for the mother's educational level and family income were less than 0.001, showing a substantial difference existing. These trends could be found in the regression model, where the type of university showed significance within the full model with a *p-value* of almost 0.05, while family income was significant in all nine models. Furthermore, the mother's educational level significantly influenced three out of nine models. The mother's educational level and other significant factors in ANOVA may be the potential factors influencing undergraduate students' CTD despite the small influence. Consequently, the comparisons can prove the correctness of the final selection after the comprehensive analysis of the regression model, while the difference identified in ANOVA cannot be ignored completely.

6. Discussion

6.1. Discussion on research questions

6.1.1. Discussion on the differences among subdimensions of each demographic factor separately

The differences for research question 1 were found for the type of university, parents' educational level, and family income. Although some studies regarding CTS concluded the no difference between the type of universities (e.g., Loken, 2005), it seemed to be ignored that no studies were found on CTD about the type of university except one study with muddy results (Rubab et al., 2021) that the statement showed no difference but a significant *p-value* was followed. The plausible explanation for the higher level of CTD of students in public universities may be that the student's college entrance scores were higher for public university students indicating a stronger intelligence; besides, public schools, supported by the government, can provide more chances for students to cultivate their habit for thinking critically by international exchange, collaboration, and communication. Concerning parents' educational levels, despite few studies, the significantly similar influence of these factors could also be found in previous studies. For example, the findings in the study of Karahan and Iskifoglu (2020) concluded the strong influence of the mother's education levels on undergraduates' CTD while little of the father's educational levels, which was almost consistent with the results in this study. The possible explanation could be inferred that the parents with higher degrees may be knowledgeable to influence their children's thinking on judging statements from a critical perspective. As the essential influence of family income was identified in the comprehensive regression models, it will be discussed in Section 6.1.2.

Regarding the no-difference factors, the similar finding was obtained that no gender difference in undergraduates' CTD (Biber et al., 2013; Boso et al., 2021; Demirbag et al., 2016; Kilic et al., 2017; Koyunlu Unlu & Dokme, 2017; Liu & Pásztor, 2022c; Mousazadeh et al., 2021; Najafi et al., 2022; Özyurt, 2015; Shida et al., 2018; Stupnisky et al., 2008; Yenice, 2011) despite the identified distinctions in previous studies (Álvarez-Huerta et al., 2022; Bers et al., 1996; Bilen et al., 2013; Bravo et al., 2020; Kırbaşlar & Özsoy-Güneş, 2015; Li, 2022; Ma, 2021; Park, 2019; Walsh & Hardy, 1999). Both results in previous studies left a further research need to explore gender differences and equality regarding CTD. In regard to academic majors, Walsh and Hardy (1999) found a higher level of CTD in English, psychology, nursing, and non-practical majors. However, no difference was found between health education majors and health sciences majors (Broadbear et al., 2005), and between engineering and non-engineering majors (Ma, 2021), Although mixed results have been obtained, CTD needs to be mastered for students in all majors in this smart and complex world. As for the residence of students, Huang et al. (2016) concluded the distinctions between Chinese urban and rural medical students' CTD, and Eldeep and Soliman (2019) also found the difference among Egyptian nursing students, which were opposite to the findings in this study. It can be explained plausibly that the samples in this study were mixed with students in arts and sciences (including medical and nursing students). People may infer that there may be a gap between students from urban and rural areas in students' habits of thinking. However, with the development of the internet and smart technology, the gap may be narrowed, which may be the reason why no gap was found in this study.

Among the potential factors, the special one is the year of study, even though the F test of year of study is significant, as the equal variance cannot be found, the selected post hoc test of Dunnett T3 did not find differences among each subdimension, which may be

because the F and p values are pretty close to the cutoff (2.59 and < 0.05, respectively). Thus, no difference was labeled among the year of study. However, for the raw score single-factor variance analysis studies, the same results were found that there was no age or year of study difference (e.g., Boonsathirakul & Kerdsomboon, 2021; Gezer et al., 2017; Liu et al., 2019; Liu & Pásztor, 2022b; Yenice, 2011); nevertheless, some studies still found a difference among ages or year of study (e.g., Boso et al., 2021; Mousazadeh et al., 2021). However, as most studies obtained no difference, this general conclusion is acceptable. Since the single-factor variance analysis cannot explain much of the influence, detailed explanations of results will be conducted in the regression model.

In general, because of the complexity of social research with different samples from different countries and different cultures in different research times and different social backgrounds. Researchers cannot find all-same samples to do consistent research with others. This study tried to do that as researchers to find the possible truth and principles for the betterment of educational sciences. Besides, nearly all previous studies adopted the raw scores for calculation instead of PVs. Thus, the differences among studies on the same topic can be accepted in this regard.

6.1.2. Discussion on the robust linear regression model result

To consider all the potential influencing factors together for research question 2, nine regression models were built one by one based on the stepwise procedure. Finally, the selected significant model was that with only family income as the influencing factor. The underlying logic for why other factors were removed is that if the added factor itself is insignificant or makes the existing factor insignificant, these insignificant factors should be deleted. The same trend of the influence of family income was found in previous studies (e.g., Huang et al., 2019) that students from higher-income families may obtain stronger CTD in Chinese medical undergraduate students. However, some other studies concluded no difference for most demographic factors without exploration of the influence of family income (e.g., Karahan & Iskifoglu, 2020; Zhang et al., 2010). Thus, given the variety of the participants' majors, not adhering to medicals in this study, and the adoption of PVs for the model analysis, the general conclusion can be made and accepted that if all potential factors in this study are considered together, the most influencing factor is the family income, and other factors effects are not obvious.

Furthermore, the plausible explanations for the reasons why the CTD of the students from higher-income families will be stronger are: (a) Students from higher-income families can touch novel things, including smart equipment or updated news, easily and instantly, which can stimulate their disposition to recognize the value and effectiveness and promote their deep and logical thinking to solve these problems caused by these new things experiencedly; (b) generally, the level of the social economic status directs to the self-confidence in most fields in daily life, still including CTD. Those with lower status may be less confident in making a fast and correct judgment and decision, considering the possible consequences of being burdened with less money, and giving it up; (c) The higher-order thinking training may happen earlier for higher-income-family students. They have more possible opportunities to know the importance of CT in the 21st century and may participate in thinking when they are young. To complement these possible reasons here, research into additional explanations should be carried out in the future.

6.1.3. Discussion on comparison between basic difference analysis and regression analysis

To compare the results between ANOVA and regression regarding research question 3, as ANOVA can be treated as a particular case of regression analysis, similar trends can be found between them. However, regression analysis can generate the edge of the influence instead of just the variance between groups, considering all the dimensions of each factor together to predict the dependent variable. To conclude, ANOVA can be the basis for the selection of influencing factors for further regression analysis, for the more significant variance found in the regression model earlier via a stepwise approach, and for the final results generated based on the regression model.

6.2. Research limitations and future directions

Although this study reached positive results, it still had limitations. Based on these drawbacks, clear future directions should be carried out. (a) The independent variables in this study are only demographic categorical factors. The R^2 of the final model identified in this study was 4.60%. Even though all the factors were integrated into the full model, the R^2 of the model was just 10.90%. Despite the acceptance of 0.1 based on other acceptable cutoffs in the social sciences (Ozili, 2023), almost 90% to 95% variance cannot be explained by these demographic variables, which requires further study to explore the influence of other demographic or continuous (observed or latent) factors on undergraduate students' CTD. (b) The participants are undergraduate students from part of southwest China. The general results cannot be extended everywhere around the world; thus, more research is needed to enrich the knowledge of this field. (c) Different countries may have different factors because of various cultures, beliefs, and races. Therefore, each country would need to go through the full set of studies. (d) Although the analysis of the PVs is more exact than the adoption of raw scores (Lechner et al., 2021; Scharl & Zink, 2022), this study only concludes three plausible explanations mentioned above without providing robust evidence for the significance of family income and less influence of other factors. Thus, future studies can adopt PVs to analyze students' CTD levels and explore more rational explanations for the results. (e) The higher educational levels of parents may lead to higher family income. However, this study did not consider such a complex correlation in the regression model. Therefore, future studies could also add an interactive factor of the parent's educational level and family income, which may demonstrate more convincingly the influence of these factors on undergraduate students' CTD.

6.3. Educational implications

This study explores the potential demographic factors that may influence undergraduate students' CTD. Based on these results, educators need to know their students' backgrounds well to understand the differences between them and the family elements affecting students' CTD levels and to balance the focus on students with both high and low levels of CTD. In particular, educators need to help those from low-income families to promote their CTD without discrimination or damaging their self-respect due to their SES level. Additionally, as educators are closest to students and mastered more CT knowledge, they may know more than others (even parents) about students' attitudes and dispositions regarding CT, and have an impact on students' acquisition (Li et al., 2022). Thus, instructors are suggested to try to find out more factors that may impact students' CTD, raise awareness of how these factors have an impact on the differences between students, and plan activities which will promote CTD for all students.

7. Conclusion

This study took a unique approach by utilizing PVs instead of traditional raw scores and employed a robust multivariate linear regression with dummy demographic variables. The investigation examined both the individual differences within each factor and the collective influence of all factors. The findings revealed that when analyzed separately, differences in CTD were observed based on factors such as university type (public or private), year of study level, parents' educational levels, and family income. However, when integrated into a comprehensive robust regression model, it was determined that family income emerged as the sole influential factor on CTD. Notably, individuals from families with the highest income level exhibited higher CTD levels than others. While the explanation of the variance of demographic factors is 5%–10%, future studies need to explore more factors that may significantly influence undergraduate students' CTD. Furthermore, it is crucial for instructors to acknowledge the impact of family income on CTD and to proactively devise effective strategies to enhance CTD among students from less affluent backgrounds. Recognizing the disparity in CTD prevalence based on family income is a critical step in creating an inclusive learning environment that supports and fosters the development of CTS for all students, irrespective of their socioeconomic status.

Ethical approval

Participants and the university research committee both gave their consent by ethical standards. Approval Committee: The Institutional Review Board (IRB) of the Doctoral School of Education, University of Szeged. Approval number: 11/2021.

CRediT authorship contribution statement

Yong Liu: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing – original draft. **Attila Pásztor:** Supervision, Funding acquisition, Writing – review & editing.

Declaration of Competing Interest

We have no conflicts of interest to disclose.

Data availability

Data will be made available on request.

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