Assessing Undergraduates' Critical Thinking Disposition: A Top University in China as a Case Study

Sheping Tian
Shanghai Jiao Tong University

Lijuan Wang
Shanghai Jiao Tong University

Wenfeng Shangguan
Shanghai Jiao Tong University

Xiaoling Ji
Shanghai Jiao Tong University

Feng Zhang
Shanghai Jiao Tong University

The study focused on assessing critical thinking (CT) dispositions among Chinese undergraduate students using the CCTDI-CV. Results showed neutral CT dispositions among students at a top university in China, with factors like gender, grade level, extracurricular activities, Research Program participation, time spent on activities, and mentor supervision influencing CT disposition. Interviews with faculty, students, and administration officials helped identify these factors' impact on students' CT disposition. Recommendations included emphasizing CT development, incorporating active teaching methods, integrating active learning in education, and ensuring systematic support for CT cultivation. The study aimed to enhance students' CT abilities through targeted strategies tailored to the university context.

Keywords: critical thinking, critical thinking disposition, factors, California Critical Thinking Disposition Inventory

INTRODUCTION

Critical thinking (CT) is an important component of students' intellectual quality and creativity (Qian, 2018), and to cultivate CT skills is a common goal of higher education in the world (Facione, 1990). A test co-sponsored by the United States, China, Russia, and India found that Chinese students experienced a decline in both CT ability and academic skill levels after graduating from university (Loyalka, et al., 2021). Further research shows that while the decline in CT among students at top universities in China was not statistically significant, the decline in CT among students at ordinary universities in China was the most

pronounced, amounting to 0.51 standard deviations. Surveys on college students' CT disposition have been conducted, and the results from the Chinese version of the Californian CT Disposition Inventory (CTDI-CV) indicate that the Chinese college students are overall ambivalently or negatively disposed toward CT (e.g., Liu & Zhao, 2010; Gao, 2013; Wang, 2015; Li, Han & Zhong, 2019; Hou, 2021; Gu, 2013; Han, Chen, & Zhang, 2007; Li & Shan, 2022). By contrast, survey results from the Californian CT Disposition Inventory (CCTDI) show that American college students are overall positively disposed toward CT (Giancarlo & Facione, 2001; Dennett & DeDonno, 2021).

With the deepening of higher education reform in China, the teaching in universities and the students' learning behaviors are continuously evolving. For example, many universities in China have conducted ongoing training of teachers in pedagogical skills; teachers continue to explore advanced teaching modes and methods to adapt to the new era of education and teaching; new teaching and learning modes such as online teaching and blended learning are rapidly expanding in order to adapt to the development of higher education and to cope with the changes in the educational environment, such as the epidemic of COVID-19 (Yuan, Zhou & Xie, 2022; Ao, Wang & Tang, 2020). In this context, to assess the CT abilities of university students is a necessity. Therefore, the questions may include: What is the status of students' CT ability? What are the factors that affect students' CT ability? How and in what ways should universities promote the development of students' CT ability? Thus, we chose the undergraduates at a top university in Shanghai of China (TUC thereafter) so as to assess their CT ability by the Chinese version of the California Critical Thinking Disposition Inventory (CCTDI-CV). It is hoped that the results of this research will improve the cultivation of undergraduates' CT ability.

CRITICAL THINKING AND RESEARCH HYPOTHESES

CT can be traced back to reflective thinking, defined by Dewey as the type of thinking that consists of turning a subject over in the mind and giving it serious and consecutive consideration, which can be used to evaluate the quality of judgment(s) (Dewey, 1933). Since then, many definitions of CT have been proposed (e.g., Paul, 1995; Watson & Glaser, 1994; McPeck, 1990; Facione, 1990). It is generally accepted that CT refers to "reasonable, reflective thinking that is focused on deciding what to believe or do", "thinking about your thinking, while you're thinking, in order to make your thinking better", and "skillful, responsible thinking that is conducive to good judgment because it is sensitive to context, relies on criteria, and is self-correcting." (Nosich, 2021: 1-2). CT can be considered from two perspectives: skills and dispositions. Researchers from different fields agree that a critical thinker must possess both a set of thinking skills and the habits of mind necessary to use those skills. The latter could be called "critical spirit" or CT disposition. The ideal critical thinker can be characterized not merely by her/his thinking skills but also by how s/he approaches life and living in general. CT disposition can be evaluated through surveys such as the California Critical Thinking Dispositions Inventory (CCTDI), which assesses how students feel when they approach the seven qualities as shown in Table 1: truth-seeking, open-mindedness, analytical tendencies, systematic tendencies, CT self-confidence, inquisitiveness, and cognitive maturity (Facione et al., 1994). Empirical studies found that there is a significant positive correlation between CT skills and the CT dispositions (Facione, 2000; Zin & Eng, 2014). In addition, the relationship between CT disposition and skills is mutually reinforcing, i.e., people with high CT disposition are more willing/accustomed to learning and utilizing CT skills. Similarly, and people with higher CT skills are more inclined to use CT to think about problems (Facione, Sanchez, et al. 1995). Thus, CT disposition is an important aspect of CT and it contributes significantly to the learning and utilization of CT skills.

CT can be trained through acquired learning. Although the lecture-based learning is a venerable and popular approach to content delivery in higher education, it does not encourage active learning or CT on the part of students (Duron, Limbach & Waugh, 2006). In contrast, active learning activities engage students in deep rather than surface learning, and enable students to apply and transfer knowledge better. It helps promote higher order thinking skills such as application of knowledge, analysis, and synthesis. Thus, active learning approaches such as engaging students with the course material through discussions, problem solving, case studies, role plays and other methods place more responsibility on the learner than passive

approaches such as lecture-based learning. Education research shows that incorporating active learning strategies into university courses significantly enhances student learning experiences and increases CT disposition as well as CT skills (Walker, 2003; Freeman, Eddy, et al., 2014; Kusumoto, 2018).

TABLE 1
DEFINITIONS OF CT DISPOSITION QUALITIES

Disposition	Definition
Truth seeking	Being eager to seek the best knowledge in a given context, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's self-interests or one's preconceived opinions
Open-mindedness	Being tolerant of divergent views and sensitive to the possibility of one's own bias
Inquisitiveness	One's intellectual curiosity and desire for learning
Analyticity	Prizing the application of reasoning and use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene
Systematicity	Being orderly, organized, focused, and diligent in inquiry
Self-confidence	Trusting the soundness of one's own reasoned judgments and leading others in the rational resolution of problems
Maturity	Approaching problems, inquiry, and decision making with a sense that some problems are necessarily ill-structured; some situations admit more than 1 plausible option; and judgments being made based on standards, contexts, and evidence that preclude certainty

For the reasons above, we will focus on the research of the CT disposition, taking it as an entry point to investigate the status of undergraduates' CT ability, and to assess the key factors affecting the CT ability of undergraduates. Two research hypotheses are thus proposed as follows:

H1: *University students' CT disposition is significantly correlated with demographic factors such as gender, grade, discipline, etc.*

H2: *Active learning such as participating in extracurricular science and technology activities, participating in Participation in Research Program (PRP), etc. has a significant role in promoting the students' CT disposition.*

RESEARCH METHODS

Research Design

Undergraduates at TUC were selected as the research participants. TUC is a comprehensive research-oriented university with a full range of disciplines. About 17,000 students are enrolled in TUC every year. The investigation was divided into two stages. In the first stage, the CTDI-CV was used to investigate the level of CT disposition of undergraduates at TUC. In the second stage, interviews were conducted with some teachers and students as well as the director of Office of Educational Administration to verify the status of the undergraduates' CT disposition from the perspectives of teaching, learning and administrative management.

In addition to CT disposition, factors that may affect CT disposition were also investigated (see Table 2).

TABLE 2
DEMOGRAPHIC VARIABLES AND ACTIVE LEARNING FACTORS ON CT DISPOSITION

Variable		Content	Value
demographic variables	X1	gender	1: male; 2: female
	X2	grade	1: freshman; 2: sophomore 3: junior 4: senior
	X3	discipline	1: engineering; 2: science 3: arts
	X4	taking a second major	1: yes; 0: no
	X5	college entrance examination score	/
active learning factors	X6	participating in extracurricular science and technology activities	1: yes; 0: no
	X7	participating in PRP (Participation in Research Program)	1: yes; 0: no
	X8	participating in Innovation and Entrepreneurship Training Programs	1: yes; 0: no
	X9	participating in laboratory traineeships	1: yes; 0: no
	X10	participating in science and technology contests	1: yes; 0: no
	X11	participating in other scientific and technical activities	1: yes; 0: no
	X12	time spent on extracurricular science and technology activities	1: 0-2 hours/week; 2: 2-4 hours/week ; 3: above 4 hours/week
	X13	Having studied or traveled abroad	1: yes; 0: no
	X14	availability of advisors	1: yes; 0: no
	X15	participating in student clubs	1: yes; 0: no
	X16	time spent on student clubs	1: 0-2 hours/week; 2: 2-4 hours/week; 3: above 4 hours/week
	X17	participating in volunteer activities	1: yes; 0: no
	X18	number of volunteer activities	1: 1 times; 2: 2 times; 3: 3 times; 4: above 3 times
	X19	number of books read outside the profession	1: 0-3 books; 2: 3-5 books; 3: above 5 books
CT		CT disposition score	70~420

Instrument

A Chinese version of CCTDI (CTDI-CV) was used to evaluate the participants' CT disposition. It was localized from CCTDI by Peng et al. (2004) and was widely used to measure Chinese students' CT disposition. CTDI-CV retains seven sub-scales which correspond to the seven qualities of CT disposition as CCTDI with 10 items per sub-scale, including 30 positive scoring items and 40 reverse scoring items. All responses to the items were rated on a six-point Likert scale ranging from "strongly disagree" (one point) to "strongly agree" (six points). The content validity index (CVI) of CTDI-CV is 0.79, with the sub-scale CVIs ranging from 0.6 to 1. The overall Cronbach alpha is 0.90 with sub-scale alphas ranging between 0.54 and 0.77. Thus, CTDI-CV can suitably reflect the CT disposition of Chinese students.

Data Analysis and Processing

For the questionnaire survey, a whole cluster random sampling method was used and students were paid to participate on a voluntary basis. Altogether 21 lecture classes were randomly selected with majors and grades evenly distributed. During the survey, research members obtained the consent of the instructors of the classes and went into classrooms to invite the students to participate in the survey. An electronic

version of the questionnaire was distributed online for students to fill out. All the undergraduates were given the opportunity to complete the questionnaire and they may also do the survey. Upon completion of the survey, every participant received a small gift. The date for completing the questionnaire survey was from 2022.12.05 to 2022.12.17 and 1018 questionnaires were returned. 263 invalid questionnaires with incomplete or repetitive answers were excluded, and 755 valid questionnaires were obtained with an effective rate of 74.2%. The demographic information of the respondents is shown in Table 3.

CT disposition is influenced by many factors, including culture, education, family background, social environment, and personal experiences, etc. (Ma, 2021; Huang et al., 2015) These factors may influence a person's values, beliefs, attitudes, and behaviours, which in turn may affect their CT. In order to examine the current status of CT disposition of undergraduates at TUC, in addition to the social factor of gender (X1) and the basic educational background (X2 to X5), we focused on the undergraduates' cultural and educational background of the university. TUC provides undergraduates with the opportunities to participate in student clubs and voluntary activities. Undergraduates also have ample opportunities to participate in a variety of science and technology activities such as Participation in Research Programs, Innovation and Entrepreneurship Training Programs, laboratory traineeships, science and technology contests, etc. These factors correspond to the demographic variables X6 to X18. Since there is a well-established relationship between reading comprehension and CT (Aloqaili, 2012; Tung & Chang, 2009), we have the number of books read outside of class as the variable to be examined (X19).

TABLE 3
THE SUMMARY OF SAMPLE DEMOGRAPHY (N=755)

Background		Frequency (n)	Percentage (%)
gender	male	568	75.2
	female	187	24.8
grade	freshman	144	19.1
	sophomore 3: junior 4: senior	237	31.4
	junior	215	28.5
	senior	159	21.0
discipline	engineering	682	90.3
	science	44	5.8
	art	29	3.9
professional studies	with a minor	139	18.4
	without a minor	616	81.6
participating in extracurricular science and technology activities	yes	359	47.5
	no	396	52.5
studied or traveled abroad	yes	10	1.3
	no	745	98.7
availability of advisors	yes	282	37.4
	no	473	62.6
participating in student clubs	yes	406	53.8
	no	349	46.2
number of extracurricular books read in one semester	0-3	439	58.2
	3-5	173	22.9
	above 5	143	18.9

For the interview survey, we invited the interviewees by email to obtain permission and then made an appointment for the time and place of the interview. The interview agreement was signed to stipulate the purpose, scope, process and confidentiality matters of the interview. The interview method was used in this

research to complement the questionnaire method to dig deeper into the reasons for the formation of undergraduates' CT disposition. The interviewees were paid for the interview.

Four undergraduates (Table 4) and four teachers (Table 5) were interviewed to investigate the students' life and learning status and the teachers' teaching approaches. The questions in the interview are as follows:

The questions for student interview include: *1) What is your general approach to learning? (Depending on the situation, passive and active learning can be pursued when appropriate) 2) In the classes you have taken, did the teacher ask questions often? What does the teacher do if a classmate can't answer or gives a wrong answer? 3) What do you do when you realize that the ideas presented by your teacher do not match your own understanding? 4) Are there many opportunities for communication and discussion among students? Are there any arguments? 5) When doing homework, is it done independently or after discussion with classmates, or in any other way? 6) In the courses you have taken, did the teacher pay attention to the reactions of your classmates? Please describe it. 7) How do you organize your time outside university? Do you participate in any university -organized activities? You can talk about the details of the activities. 8) What do you think is the biggest change after entering TUC? Especially in terms of learning methods and ways of thinking. What caused these changes?*

The questions for teacher interview include: *1) What is the usual format of your lectures? What formats do you find distinctive? 2) What is the typical format of your interactions with students? 3) What approach do you take when a student presents a different view or perspective on the topic you are teaching? 4) How do you usually deal with students who want to ask you for advice when they have a problem? 5) Do you supervise students for thesis writing, undergraduate graduation design, graduate student dissertation, students' extracurricular scientific and technological activities, etc.? Please tell us about your specific practices. 6) What do you think the strengths and weaknesses of TUC in training students?*

Additionally, interviews with the director of the Office of Educational Administration were scheduled to understand the state of education and teaching across the university.

TABLE 4
INFORMATION OF THE INTERVIEWED STUDENTS

Student ID	Gender	Grade	Major
S1	female	sophomore	Information engineering
S2	male	senior	Measurement and control technology and instruments
S3	female	junior	English
S4	male	junior	Electrical engineering

TABLE 5
INFORMATION OF THE INTERVIEWED TEACHERS

Teacher ID	Gender	Job title	Length of teaching
T1	male	Teaching and research /Associate Professor	25
T2	male	Teaching and research / Professor	12
T3	male	Teaching and research /Associate Professor	29
T4	female	Teaching/Lecturer	21

The data from the questionnaire were analysed and processed by using SPSS 24.0.

RESULTS

Students' Overall CT Disposition

According to the instructions of the CCTDI manual (Facione & Facione, 1992): a total overall CT disposition score between 210 and 280 indicates an ambivalent CT disposition; a score lower than 210

indicates a negative CT disposition; a score higher than 280 indicates a positive CT disposition. A score of less than 30 on each of the seven CT qualities indicates a poor CT disposition, which is negative; a score between 30 and 40 indicates an ambivalent CT disposition, which is neutral; and a score of more than 40 indicates a positive CT disposition. The overall average CT disposition score of the undergraduates at TUC is 231.75 ± 24.175 which indicated the CT disposition is ambivalent. Of the seven qualities, only the score of cognitive maturity exceeded 40, which is positive; analytical tendency, CT self-confidence, and inquisitiveness are below 30, which is negative; and the other three qualities are below 40, which is neutral (see Table 6).

TABLE 6
STATISTICAL CT DISPOSITION SCORES BY GRADE LEVEL AND GENDER (MEAN±SD)

	truth-seeking	open-mindedness	analytical tendencies	systematic tendencies	CT self-confidence	inquisitiveness	cognitive maturity	overall score
freshman	37.09±7.029	34.28±5.223	27.63±4.841	31.92±4.582	26.27±5.898	28.74±5.320	41.97±6.083	227.90±22.839
sophomore	36.96±7.251	34.2±5.833	28.36±5.371	31.69±5.328	26.6±6.723	28.66±5.886	41.55±6.618	228.02±27.749
junior	38.77±7.309	35.39±5.016	29.31±4.245	33.14±4.529	27.2±5.956	28.93±5.593	42.00±7.092	234.74±21.346
senior	39.34±7.22	35.18±4.811	29.22±3.833	33.14±4.516	27.58±5.413	29.41±4.636	42.9±6.854	236.77±21.857
male	37.84±7.611	34.49±5.540	28.52±4.817	32.22±5.016	26.65±6.208	28.57±5.450	41.76±7.030	230.06±25.440
female	38.48±6.147	35.59±4.412	29.14±4.302	33.16±4.200	27.72±5.687	29.93±5.326	42.89±5.581	236.91±18.995
total	37.99±7.277	34.76±5.302	28.67±4.700	32.45±4.841	26.92±6.097	28.91±5.447	42.04±6.714	231.75±24.175

Significance Tests Between CT Disposition and Other Variables

From the histogram of standardized residuals of CT disposition scores (see Figure 1) and the probability plot of normal distribution of standardized residuals (see Figure 2), the CT disposition scores do not satisfy normal distribution. This was also validated by the normal distribution test with p = 0.001. For this reason, the Wilcoxon rank-sum test was used to test for significance.

FIGURE 1
HISTOGRAM OF STANDARDIZED DEVIATIONS OF THE SAMPLES

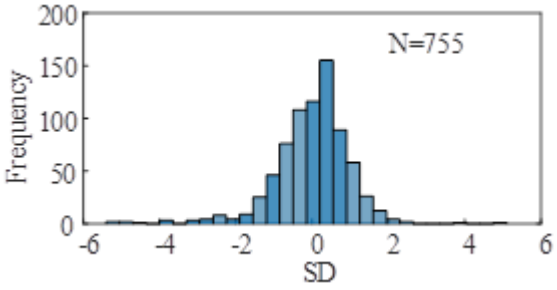
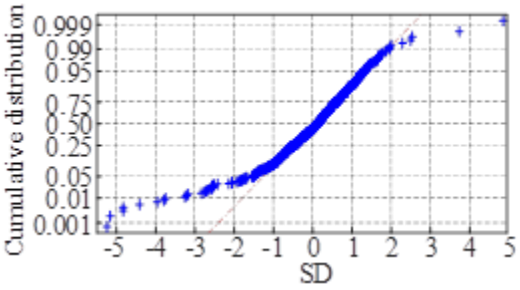


FIGURE 2
NORMALLY DISTRIBUTED PROBABILITY OF STD. DEVIATIONS OF THE SAMPLES



The Wilcoxon rank-sum test reveals significant differences in CT disposition with demographic variables X1, X2, X6, X7, X12, and X14 (see Table 7), and no significant differences with other variables.

TABLE 7
RESULTS OF SIG. TEST FOR CT DISPOSITION WITH VARIABLES. X1, X2, X6, X7, X12, X14

Variable	Value	CT Disposition Score	*p*
X1：gender	male	230.06	0.000**
	female	236.91	
X2：grade	freshman	227.90	So. and Fr.： 0.854 Jr. and Fr.： 0.001** Sr. and Fr.： 0.000** Jr. and So.： 0.000** Sr. and So.： 0.000** Sr. and Jr.： 0.421
	sophomore	228.02	
	junior	234.74	
	senior	236.77	
X6：extracurricular sci. & tech. activities	no	229.30	0.019*
	yes	233.98	
X7：research projects	no	229.58	0.000**
	yes	238.49	
X12：time on extracurricular sci. & tech. activities	0	229.30	0-2 hr/wk and 0： 0.246 2-4 hr/wk and 0： 0.020* above 4 hr/wk and 0： 0.096 2-4 hr/wk and0-2 hr/wk： 0.404 above 4 hr/wk and 0-2 hr/wk： 0.627 above 4 hr/wk and2-4 hr/wk： 0.632
	0-2 hr/ wk	232.58	
	2-4 hr/wk	235.37	
	above 4 hr/wk	234.53	
	no	230.52	

X14：availability of advisors	yes	233.83	0.018**

*: p<0.05; **: p<0.01

DISCUSSION

Overall CT Disposition

The CT disposition of undergraduates at TUC is ambivalent. This result is comparable to those found in the literature: higher than those of the literature (Hou, 2021), and lower than those of the literature (Han, Chen & Zhang, 2007; Li & Shan, 2022). The overall level of the CT disposition of undergraduates at TUC is not high. This can be analyzed as follows:

1) Although there is a growing consensus that a complete approach to developing college students into good critical thinkers must include the nurturing of the disposition toward CT (Facione, 2000), indeed, too often in university teaching the development of CT skills is emphasized at the expense of the development of CT dispositions. Students with high CT disposition are more willing/accustomed to ask themselves who, what, when, where, why, and how. Such questions are open-ended and require critical and higher-order thinking skills. Nevertheless, Chinese students are generally with weak will and ability to ask questions (Gong, 2006). This mainly stems from the fact that classroom teaching in China is mostly traditional didactic teaching, where teachers usually take the lead in imparting knowledge and skills, and students are expected to be well-behaved to listen and learn in the classroom. This teaching mode makes it difficult to create an open atmosphere that encourages students to ask questions and fails to provide contexts for formulating, analyzing, and solving problems, thus limiting the development of students' CT dispositions and skills. In the teacher interviews, we asked "what kind of teaching style is usually used in your class?", and received a very consistent response of using a lecture-based style. The following are some answers from the teachers:

> "*I still teach in a traditional way, which is to utilize multimedia to aid teaching. The teaching style is the same whether it's online or offline mode.*" (T1)
>
> "*I mainly use didactic teaching. The class should start with getting the internal logic of what is being taught. You can't just talk about the what, you have to talk about the why.*" (T2)
>
> "*My classes are still mainly didactic, I am used to explaining on the board.*" (T3)
> "*I teach English reading and writing course. The teaching is based on reading and then I speak. The language needs to be carefully analyzed, and I will give some analysis of some literature in class.*" (T4)

In contrast to this kind of passive learning classroom, where teachers teach and students listen, an active learning classroom provides a proactive, challenging and cooperative learning environment for learners. Teachers using active learning strategies in the classroom will make students stronger thinkers (Bean, 2011). Questioning and challenging existing views, independent thinking, problem solving, collaboration and discussion in active learning can motivate students to move from passive to active learning, prompting them to think and evaluate information critically, develop independent views and judgments, which in turn promotes the development of the CT ability including CT disposition (Meyers, 1986). The results of several studies indicated that active learning strategies such as group discussion, scenario simulation, case research, etc. can improve students' CT disposition (Burbach, Matkin & Fritz, 2004; Tsui, 1999; Nelson & Crow, 2014).

The results of the student interviews corroborate the above viewpoints. Teachers failed to consciously design instruction from the perspective of CT disposition in their courses, and only

guided students superficially in the classroom. At the same time, students' willingness to ask or answer questions was insufficient. For example:

> "*For questions that students could not answer or answered incorrectly, the teacher usually either gave a little hint or he would explain the question clearly by himself.*" (S1)

> "*Some teachers would ask many questions but others seldom ask questions in class.*" (S2)

> "*Some teachers do particularly like to ask questions, but in many cases, students are instead reluctant to answer the questions. Even the ones who can answer don't seem to be very willing to do so. ..... One reason is the respondent really doesn't know the answer, the other is that the respondent does know the answer, but feels difficult to express the answer clearly.*" (S4)

In the interview with the director of Office of Educational Administration, he expressed the same viewpoint. He said,

> "*One of the goals of university education is to equip students with CT, and the highest level of CT (critical spirit) is the ability to ask new scientific questions. From this perspective, our undergraduates are still lacking in CT (critical spirit).*"

2) The general education and inter-disciplinary curriculum in TUC do not work as well as it should. General and inter-disciplinary education are conducive to the development of students' CT dispositions (Elliott, 1999; Pislae-ngam, 2018). Although the teaching arrangement of TUC encourages students to expand their cross-disciplinary perspectives and promote the development of innovation and CT abilities through learning general education and inter-disciplinary courses, the results show that the optimal effect has not been achieved. The chief end of some students to take these courses is to obtain enough credits required for graduation. This was confirmed in student interviews. For example,

> "*We should take more credits and have more pressure to study in the major courses, so some students who take general education or inter-disciplinary elective courses will choose those that are less difficult and easy to pass so that they can meet the credit requirements.*" (S3)

Significance Between CT Disposition and Other Variables

1) The CT disposition score of females is significantly higher than that of males in TUC. Further examination of the seven qualities of CT disposition reveals that females are significantly higher than males in open-mindedness, inquisitiveness, and cognitive maturity. This is quite consistent with that of Facione et al. (1995) where a survey of 198 freshmen and sophomores at a public comprehensive university shows that females were significantly higher than males in open-mindedness and cognitive maturity, and there is no significant difference in other qualities. The possible reasons for incomplete consistency may be two: Gender differences in CT disposition are related to the size of the sample surveyed and the type of university; The instrument itself may not have been successful in reflecting gender differences in CT disposition (Walsh & Hardy, 1999).
2) The CT disposition score is significantly higher among juniors and seniors than among freshmen and sophomores. However, there is no significant difference between freshmen and sophomores and between juniors and seniors. This result shows that the effect on undergraduate CT disposition does not begin to manifest itself until the junior year. This is in line with the findings of Ralston &

Bays (2015) who conducted a six-year study. This study is a descriptive, longitudinal one with three engineering student cohorts (50, 62, and 70 students respectively) as they progressed through the four-year undergraduate program. It is found that CT scores of juniors are significantly higher than those of freshmen and sophomores for all three cohorts, with junior and senior CT scores of the second and third cohorts significantly higher than those of freshmen and sophomores, and there is no significant difference between freshmen and sophomores and between juniors and seniors, which is completely consistent with the findings of our research. Here are the reasons for this:

Firstly, TUC has arranged a variety of extracurricular activities for undergraduates, such as student clubs, Participation in Research Program (PRP), Innovation and Entrepreneurship Training Programs (IETP), and science and technology contests, etc. which are open to all undergraduates. Relatively speaking, juniors and seniors have more knowledge and experience, and they will take on more responsibilities, take up higher positions, or be in the leadership and core position of a team. Thus, juniors and seniors may get more training when participating in these extracurricular activities and demonstrate a stronger CT disposition than freshmen and sophomores. Secondly, most students start to study professional courses after entering the junior year, and their learning mode and depth are obviously different from the basic and general courses in the freshman and sophomore years. The active learning modes, such as project-based teaching and task-based teaching are embedded into the professional courses in the junior and senior years, which makes the CT disposition of juniors and seniors change greatly.

3) As shown in Table 6, there is a significant difference between the CT disposition and participating in extracurricular scientific and technological activities, participating in PRP, and the length of time invested in extracurricular scientific and technological activities. As a top university in China, TUC has a highly qualified faculty. Many teachers in TUC have extensive experiences in research. All the undergraduates at TUC could participate in the research activities if they are willing to do so. They could even take part in some cutting-edge research programs. The PRP of TUC is a special research program for undergraduates since 2001, which aims to let undergraduates participate in extracurricular research projects in an organized and planned way. Through this program, students can receive basic training in research as soon as possible, cultivate the interest and ability in research, and lay a solid foundation to further participate in research. TUC is one of the first universities to implement the PRP in China which is characterized by standardized implementation and management. Generally, most of the PRP projects come from faculty members' research projects and the difficulty of the projects is appropriate to the level of knowledge of undergraduates. At present, PRP of TUC has been incorporated into the Student Training Programs, and all undergraduates must participate in at least one PRP project before graduation.

   TUC also implements IETP, which aims to explore and establish a problem and project-oriented teaching mode by supporting some outstanding students to carry out research. However, in this survey, there is no significant correlation between CT disposition scores and participating in IETP. Possible reasons for this include the following: First, the difficulty of the tasks of IETP projects is higher than that of the PRP projects, which may lead to a decrease in the quality of completion of the projects, thus the students' CT ability has not been systematically trained. Second, unlike the PRP projects which are initiated by the teachers, the topics of IETP projects are proposed by the undergraduates themselves. Comparatively, undergraduates are less experienced in research, which may lead to the fact that the proposed topics may not be very appropriate in terms of feasibility, difficulty, etc. On the other hand, there may also be insufficient guidance from supervisors (teachers) during the running of the program. As a result, the training effect on undergraduate students is not outstanding. Third, in IETP, the student is the applicant, he/she is also the head and executor of the project. This leads to the weakening of supervision, guidance and training, which may also weaken the development of the CT ability.

   In terms of the time invested in extracurricular science and technology activities, there was a significant difference in CT disposition between students who spent 2-4 hours per week in extracurricular activities and those who invested 0 hours, with the former scoring significantly

higher than the latter. Generally, devoting more time and energy to study will increase the depth and breadth of learning, improve the mastery of knowledge and skills, broaden the horizons, and lay the foundation for the development of CT ability. However, the time undergraduates devote to activities is limited, and if they devote too much time to extracurricular science and technology activities, the time for course study will be reduced, thus affecting the learning effect. The CT ability will not be trained properly if not enough time is spent. According to the survey results, spending 2-4 hours per week to extracurricular science and technology activities has the best impact on CT disposition.

Extracurricular science and technology activities are typical active learning activities. The above results and discussion suggest that even active learning activities, if they are not reasonably organized and scheduled, their learning effects may fall short of expectations. From the university level, it is hoped that extracurricular science and technology activities such as PRP and IETP activities can well develop undergraduates' CT. The findings suggest that PRP promotes the development of undergraduates' CT skills, while IETP does not achieve this goal.

4) Availability of advisors has a significant effect on CT disposition. Undergraduate mentorship aims to allow undergraduates to gain a deeper understanding of their majors, academics, and continuous self-improvement through the guidance of mentors. Undergraduates at TUC usually select a professional faculty member as their advisor in their first semester. This system allows undergraduates to adapt and integrate into university life faster and better, and establishes academic dialog and communication between faculty and students. The undergraduate mentoring system closes the relationship between teachers and students, making the advisors have a more direct impact on the undergraduates. Excellent undergraduate advisors can provide support and assistance to students in all aspects of development, including the development of CT ability (Frost, 1991).

SUGGESTIONS

Innovation has become the first driving force to lead development. China has promulgated "The Outline of the National Innovation-Driven Development Strategy" in 2016 to propose to build a world power in science and technology innovation by 2050, and to become the world's major scientific center and innovation highland. Innovation and CT are closely related and mutually reinforcing. CT is the foundation of innovation, and innovative thinking is the goal of CT (Khumalo & Plessis, 2023). CT is one of the indispensable abilities in the innovation process, which helps people challenge established ideas, inspires innovative thinking, and ensures the rigor and logic of the innovation process. Therefore, developing students' CT ability is one of the most important tasks of higher education in China, and in other countries as well. Specific suggestions are as follows:

(1). *Attaching great importance to the development of students' CT ability from top to bottom*. It has been found that the CT disposition of Chinese students is significantly lower than that of students in developed countries. This is closely related to the fact that higher education in China has not paid enough attention to the cultivation and development of students' CT ability. Taking TUC as an example, although it has occurred gradually that students are asked to analyze challenging real-life problems to enhance their CT disposition in some teaching practice, it has not become an institutionalized measure and formed a broad consensus. In addition, cultivating CT dispositions and qualities is more important than cultivating CT skills. Because CT disposition is a personality attribute, including the individual's motivation, beliefs, attitudes, and habitual ways of responding, etc., it will directly determine the specific behavioral responses. The formation of CT disposition and quality will not be achieved overnight, but requires long-term top-down all-round attention and cultivation.

(2). *Reforming the traditional classroom teaching mode*. Teachers in China's universities are generally accustomed to the "knowledge transfer" mode of teaching in the classroom, and they do not attach much importance to the discovery and formulation of problems. Even when teachers ask questions in classrooms, they often tend to give so-called standard answers. This

mode of teaching does not help much in the training of students' CT ability, especially CT disposition and quality. In view of this, higher education should be truly student-centered, building a good environment and atmosphere for free exploration, encouraging students to ask questions.

In this regard, the course called Building Mechanics offered by the School of Shipbuilding, Oceanography and Architectural Engineering at TUC can be a good example. In this course, the lecturer puts forward a task to the students firstly: to design a building structure with a certain load-bearing capacity. After the students complete the design, the teacher puts forward a second task: try to reduce the mass of the structure of the original design by 20%. Obviously, the second design solution is going to subvert the student's first design solution, and the CT ability occurs or develops in the process of completing the second design solution. This will motivate students to explore further: even trying to reduce the mass of the structure by another 10%. This student-initiated participatory teaching approach fully develops students' CT skills. This example illustrates that the goal of developing CT ability can be achieved within the specialized courses by optimizing teaching methods or instructional design.

In fact, there are several ways to develop CT ability: 1) offering specialized courses about CT; 2) embedding CT development into regular classroom teaching; and 3) developing courses that implicitly incorporate CT cultivation. To effectively combine discipline teaching and CT training is more helpful. Integrating CT ability cultivation into existing curriculum without changing the existing teaching mode is the most economical and feasible method, and it is also the most common method for discipline teachers to conduct CT training for students (Alsaleh, 2020). There are many teaching methods that can effectively develop students' CT abilities, such as cooperative learning (Nelson, 1994; Gokhale, 1995), research-based learning (Susiani, Salimi & Hidayah, 2018), project-based/case-based teaching (Sapeni & Said, 2020; Saleewong & Suwannatthachote, 2012), inquiry-based learning (Duran & Dökme, 2016; Ghaemi & Mirsaeed, 2017), and problem-based learning (Masek & Yamin, 2011; Liu & Pasztor, 2022). Even in traditional lecture-based teaching, the development of students' CT skills can be achieved through the careful design of questions (Nappi, 2017).

The development of students' CT ability can also be promoted in conjunction with the work of Teaching Development Centers in each university. Taking TUC as an example: The Center for Teaching and Learning Development has been organizing a wealth of teaching seminars and training activities since its establishment. Embedding training modules related to CT ability development in these activities can change teachers' teaching philosophy and update their teaching methods, thus enhancing the effectiveness of developing students' CT ability in classroom teaching.

(3). *Embedding active learning approaches in as many daily educational and teaching activities as possible*. For example, PRP activity in TUC is one of active learning reforms. It is a kind of authentic problem-based research and learning and enables learners to engage in meaningful and purposeful activities like practitioners or experts, and to transfer and apply the acquired knowledge and experience to solve social life problems effectively (Yuliati, Fauziah & Hidayat, 2018). Active learning can be conducted applying a variety of instructional models such as cooperative learning and research-based learning as mentioned above. The common feature of these teaching modes is to encourage students to participate in learning actively and develop their abilities in self-directed learning, problem solving and team cooperating.

Active learning can be applied to both inside-classroom and outside-classroom teaching. Especially in the outside-classroom case, students will have more time and opportunities to explore topics of interest in depth, to propose problems and find innovative solutions, and thus to deepen their understanding and mastery of knowledge. This can cultivate students' independent thinking and learning abilities effectively, and make them become real active learners. TUC incorporates various types of extracurricular research activities such as PRP, IETP and scientific and technological competitions into the teaching program. This practice

deserves to be replicated. Active learning not only develops students' CT ability, but also cultivates their research ability (the ability to discover, analyze and solve problems) and innovative thinking in research, which is conducive to cultivating innovative talents who can adapt to the social and economic development of the country.

(4). *Strengthening system construction to support CT ability development*. Cultivating students' CT ability is a long-term process, which needs to be guaranteed by the institutional system. For example, the cultivation of CT ability should be incorporated into the assessment of teaching and learning; the enthusiasm of teachers to emphasize the cultivation of students' CT ability should be enhanced through the introduction of a reasonable evaluation mechanism; and teachers and students should be guided to fully recognize the importance of CT ability, to create a campus culture that emphasizes on the cultivation of CT and innovation abilities.

RESEARCH LIMITATIONS AND FUTURE WORK

With the evaluation of CT disposition of undergraduates in a top university in China as an example, this study draws some formative research conclusions and provides suggestions on the cultivation of students' CT ability. It is worth pointing out that the investigation only reflects the status of CT disposition of undergraduates at TUC. The results do not represent the overall status of undergraduates in colleges and universities in China.

In the future, we need to evaluate the status of Chinese undergraduates' CT ability on a larger scale, to provide more valuable suggestions for Chinese colleges and universities to carry out CT cultivation. In addition, the overall reliability of CTDI-CV is high, but the reliability of each dimension is not so satisfactory. This scale can be further revised to ensure that more realistic assessment data on the CT disposition of college students in China can be obtained, and then more constructive training suggestions can be made.

ACKNOWLEDGEMENTS

This work was supported by Office of Educational Administration of Shanghai Jiao Tong University, China under the Project JBDD2022-003, and in part by the Ministry of Education of China under the Project E-CXCYYR20200925 and the Teaching Advisory Committee on Instrument Majors in Higher Education under the Ministry of Education of China under the Project 2018C052. The authors would like to thank those who collaborated with the research and answered the questionnaires.

REFERENCES

Aloqaili, A.S. (2012). The relationship between reading comprehension and critical thinking: A theoretical study. *Journal of King Saud University - Languages and Translation*, *24*(1), 35–41.

Alsaleh, N.J. (2020). Teaching critical thinking skills: Literature review. *The Turkish Online Journal of Educational Technology*, *19*(1), 21–39.

Ao, D., Wang, Z.-J., & Tang, J. (2020). Mental health status and its demographic factors among pre-service teachers during the epidemic of COVID-19. *Population & Development*, *26*(5), 122–128.

Bean, J.C. (2011). *Engaging ideas: The professor's guide to integrating writing critical thinking and active-learning in the classroom* (2nd Ed.). San Francisco, CA: Jossey-Bass.

Burbach, M.E., Matkin, G.S., & Fritz, S.M. (2004). Teaching critical thinking in an introductory leadership course utilizing active-learning strategies: A confirmatory study. *College Student Journal*, *38*(3), 482–483.

Dennett, S.K. & DeDonno, M.A. (2021). A comparison between Chinese and American male and female college students' critical thinking dispositions. *International Journal of Chinese Education*, *10*(3), 1–14.

Dewey, J. (1933). *How we think* (2nd Ed.). Boston, MA: DC Heath.

Duran, M., & Dökme, İ. (2016). The effect of the inquiry-based learning approach on student's critical-thinking skills, Eurasia J. of Mathematics. *Science & Technology Education*, *12*(12), 2887–2908.

Duron, R., Limbach, B., & Waugh, W. (2006). Critical thinking framework for any discipline. *International Journal of Teaching and Learning in Higher Education*, *17*(2), 160–166.

Elliott, B.M. (1999). *The influence of an interdisciplinary course on critical thinking skills*. University of North Texas.

Facione, N.C., Facione, P.A., & Sanchez, C.A. (1994). Critical thinking disposition as a measure of competent clinical judgment: The development of the California Critical Thinking Disposition Inventory. *J Nurs Educ.*, *33*(8), 345–350.

Facione, P.A. (1990). Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction (executive summary). *The Delphi Report*. Millbrae, CA: California Academic Press.

Facione, P.A. (2000). The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill. *Informal Logic*, *20*(1), 61–84.

Facione, P.A., & Facione, N.C. (1992). *The California critical thinking disposition inventory (CCTDI) test administration manual*. Millbrae, CA: California Academic Press.

Facione, P.A., Sanchez, C.A., et al. (1995). The disposition toward critical thinking. *Journal of General Education*, *44*(1), 1–25.

Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415.

Frost, S.H. (1991). Fostering the critical thinking of college women through academic advising and faculty contact. *Journal of College Student Development*, *32*(4), 359–366.

Gao, Z.-Y. (2013). A survey on the current situation of critical thinking disposition of undergraduate of application-oriented university. *Higher Education Exploration*, *29*(20), 129–133.

Ghaemi, F., & Mirsaeed, S.J.G. (2017). The impact of inquiry-based learning approach on critical thinking skill of EFL students. *EFL J.*, *2*(2), 89–102.

Giancarlo, C., & Facione, P. (2001). A look across four years at the disposition toward critical thinking among undergraduate students. *Journal of General Education*, *50*(1), 29–55.

Gokhale, A.A. (1995). Collaborative learning enhances critical thinking. *J. of Technology Education*, *7*(1), 22–30.

Gong, M.-Y. (2006). *The theory and practice study of cultivating the college students' ability to discover and pose problems*. Hunan: Hunan Normal University.

Gu, Q.-X. (2013). Empirical analysis on undergraduates' critical thinking disposition and suggestions on its development. *Shanghai Journal of Educational Evaluation*, *2*(4), 64–73.
Han, L.-L., Chen, C.-X., & Zhang, X.-H. (2007). Investigation and analysis about the critical thinking status of college students. *China Journal of Health Psychology*, *15*(3), 245–247.
Hou, Y.M. (2021). Critical Thinking and its relevant factors among undergraduates. *Journal of Educational Theory and Management*, *5*(2), 23030.
Huang, L., Wang, Z., Yao, Y., Shan, C., Wang, H., Zhu, M., . . . Zhao, X. (2015). Exploring the association between parental rearing styles and medical students' critical thinking disposition in China. *BMC Medical Education*, *15*, 88.
Khumalo, S., & Plessis, T.D. (2023). Knowledge transfer: Graduates' capability to demonstrate and produce business innovation. *South African Journal of Information Management*, *25*(1), 1–12.
Kusumoto, Y. (2018). Enhancing critical thinking through active learning. *Language Learning in Higher Education*, *8*(1), 45–63.
Li, J.-L., & Shan, J. (2022). Research on college students' critical thinking and its relationship with learning behavior. *China Agricultural Education*, *23*(03), 62–71.
Li, N., Han, Q.-E., & Zhong, W.-X. (2019). The general situation and variation analysis of undergraduates' critical thinking: Based on an investigation in Shandong province. *China Higher Education Research*, *35*(2), 49–52.
Liu, Y., & Pasztor, A. (2022). Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis. *Thinking Skills and Creativity*, *45*(9), 1–21.
Liu, Y., & Zhao, J.-M. (2010). The investigation of undergraduate students' critical thinking disposition. *Research in Higher Education of Engineering*, *28*(1), 81–85.
Loyalka, P., Liu, O.L., Li, G., Kardanova, E., Chirikov, I., Hu, S., . . . Li, Y. (2021). Skill levels and gains in university STEM education in China, India, Russia and the United States. *Nature Human Behavior*, *5*(3), 892–904.
Ma, H.-R. (2021). Critical thinking dispositions of undergraduate college students in a comprehensive university of mainland China. *International Journal of Higher Education*, *10*(6), 224–237.
Masek, A., & Yamin, S. (2011), The effect of problem-based learning on critical thinking ability: A theoretical and empirical review. *Int. Review of Social Sciences and Humanities*, *2*(1), 215–221.
McPeck, J.E. (1990). *Teaching critical thinking: Dialogue and dialect*. New York, NY: Routledge.
Meyers, C. (1986). *Teaching student to think critically: A guide for faculty in all disciplines*. San Francisco, CA: Jossey-Bass.
Nappi, J.S. (2017). The importance of questioning in developing critical thinking skills. *Delta Kappa Gamma Bulletin*, *84*(1), 30–41.
Nelson, C.E. (1994). Critical thinking and collaborative learning. *New Directions for Teaching and Learning*, (59), 45–58.
Nelson, L.P., & Crow, M.L. (2014). Do active-learning strategies improve students' critical thinking? *Higher Education Studies*, *4*(2), 77–90.
Nosich, G.D. (2021). *Learning to think things through: A guide to critical thinking across the curriculum* 4th Ed.). London: Pearson Education Inc.
Paul, R. (1995). *How to prepare students for a rapidly changing world*. Santa Rosa, CA: Foundation for Critical Thinking.
Peng, M.-C., Wang, G.-C., Chen, L.-J., et al. (2004). Validity and reliability of the Chinese critical thinking disposition inventory. *J. of Nursing*, *39*(9), 644–647.
Pislae-ngam, K. (2018). An analysis of critical thinking skills in general education course. *Advances in Social Sciences Research*, *5*(6), 54–61.
Qian, Y.-Y. (2018). Educating students in critical thinking and creative thinking: Theory and practice. *Tsinghua Journal of Education*, *39*(4), 1–16.
Ralston, P.A., & Bays, C.L. (2015). Critical thinking development in undergraduate engineering students from freshman through senior year: A 3-cohort longitudinal study. *American Journal of Engineering Education*, *6*(2), 85–98.

Saleewong, D., & Suwannatthachote, P. (2012). Case-based learning on web using questioning techniques and reflective thinking upon critical thinking of undergraduate students. In T. Amiel, & B. Wilson (Eds.), *Proceedings of EdMedia 2012: World Conference on Educational Media and Technology* (pp. 992–997).
Sapeni, M.A.R., & Said, S. (2020). The effectiveness of case-based learning in increasing critical thinking of nursing students: A literature review. *Enfermería Clínica*, *30*(S2), 182–185.
Susiani, T.S., Salimi, M., & Hidayah, R. (2018). Research based learning (RBL): How to improve critical thinking skills? *Global Conference on Teaching, Assessment, and Learning in Education*, pp. 1–6.
Tsui, L. (1999). Courses and instruction affecting critical thinking. *Research in Higher Education*, *40*(2), 185–200.
Tung C.-A., & Chang, S.-Y. (2009). Developing critical thinking through literature reading. *Feng Chia Journal of Humanities and Social Sciences*, (19), 287–317.
Walker, S.E. (2003). Active learning strategies to promote critical thinking. *Journal of Athletic Training*, *38*(3), 263–267.
Walsh, C.M., & Hardy, R.C. (1999). Dispositional differences in critical thinking related to gender and academic major. *Journal of Nursing Education*, *38*(4), 149–155.
Wang, X.-F. (2015). Structural analysis of college students' critical thinking skills. *Journal of Wuhan Business University*, *29*(3), 77–80.
Watson, G.B., & Glaser, E.M. (1994). *Test manual: The Watson Glaser critical thinking appraisal*. San Antonio, TX: Psychological Corp.
Yuan, Z.-J., Zhou, J.-H., & Xie, Y.-L. (2022). Making home as school: Construction of alternative education space at home among Chinese undergraduates in the context of COVID-19 pandemic. *Geographical Research*, *41*(6), 1684–1699.
Yuliati, L., Fauziah, R., & Hidayat, A. (2018). Student's critical thinking skills in authentic problem-based learning. *Journal of Physics Conference Series*, *1013*(1), 012025.
Zin, Z.M., & Eng, W.B. (2014). Relationship between critical thinking dispositions and critical reading skills of Malaysian ESL learners. *Asian EFL Journal*, *16*(3), 41–68.