Yike Ying[1] [1]Humboldt-Universität zu Berlin
Rüdiger Tiemann[1]

A Comparative Analysis of Collaborative Problem-Solving Skills Among German and Chinese High School Students

Theoretical background

Collaborative problem-solving (CPS) stands out as an indispensable facet of 21st-century skills, especially within the realms of science, technology, engineering, and math (STEM) education (Chen et al., 2019; Hesse et al., 2015). Known for its efficacy in addressing real and intricate problems, CPS in STEM education plays a vital role in instilling scientific knowledge and problem-solving capabilities (Chen et al., 2019; Hesse et al., 2015). Monitoring students' collaborative abilities is crucial, particularly in the STEM framework, where a valid measurement of CPS contributes to a profound understanding of its intricate components. In chemistry, collaborative problem-solving entails negotiating and refining mental models, as well as identifying discrepancies between observed and predicted outcomes. This process draws on various styles of scientific reasoning, including hypothesis generation and testing, experimentation, and evidence evaluation.

Research aims

In most educational systems, collaboration is not explicitly taught but acquired through subject learning, making empirical research on CPS processes and products in educational environments scarce (Graesser et al., 2018). This study addresses the limited research on CPS by comparing the collaborative problem-solving skills of Chinese and German high school students in chemistry. Given the distinct cultural backgrounds and education systems in China and Germany, where Chinese culture emphasizes collective and cooperative efforts while German culture stresses individual independence and autonomy (Bluszcz & Quan, 2016), the research aims to:

- Compare differences in collaborative problem-solving skills between Chinese and German students in chemistry.
- Identify factors influencing variations in students' collaborative problem-solving skills.

Methods and design

To identify shared chemical concepts taught in both countries for designing CPS items, we compared Chinese and German curriculum standards and 10th-grade textbooks. Then based on the PISA 2015 CPS framework, which combines three main collaborative competencies with four processes of individual problem solving to produce a total of 12 CPS skills (OECD, 2017), the CPS-C tool was developed. It consists of three tasks derived from practical experience: Cola Titration (1 agent, 21 items), Fruit Battery (2 agents, 19 items), and Soap Making (3 agents, 20 items). The platform we selected for developing a measurement tool for collaborative chemistry problem-solving capabilities is LimeSurvey (LimeSurvey, 2012). Figure 1 displays the Wright map of the CPS, presenting data for Germany in the first column and China in the second. All items fall within the range of -1.5 to 2.5, covering the complete spectrum of students' ability values. The difficulty distribution exhibits a balanced trend across

the test, with items ranging from relatively easy to more difficult, indicating the tool's efficacy in distinguishing between participants with varying CPS skills.

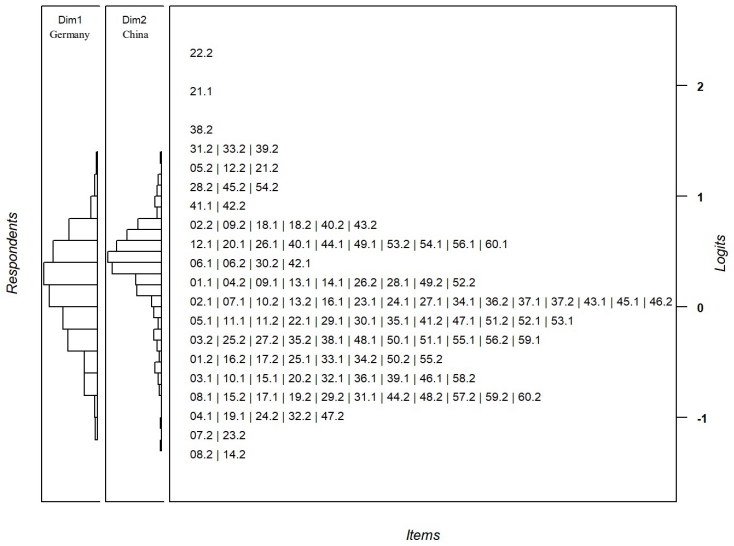

Figure 1. The Wright map of collaboration competencies

To evaluate student performance on the CPS, we scaled raw scores using Multidimensional Item Response Theory (MIRT) models in R 4.2.1 (R Core Team, 2022), and employed the Generalized Partial Credit Model (GPCM) (Muraki, 1992) for rating item scores. A total of 594 students participated in the survey—302 students (140 male/163 female) from Germany and 292 students (205 male/87 female) from China. Additionally, we incorporated an Interest and Motivation test (Rost, 2021), Cognitive Ability test (Heller & Perleth, 2000), Mental Load and Effort test (Krell, 2015), Stress test (Minkley et al., 2018), and Prior Knowledge test to assess potential effects of these factors on students' CPS skills.

Results

This study initially compared CPS performance differences between Chinese and German students. The Mann-Whitney U test revealed that the CPS performance of Chinese students (Mean rank= 344.24) was significantly higher than that of German students (Mean rank= 252.31), ($U = 57740.5$, $p = 0.000$). Regarding gender differences, the Mann-Whitney U test indicated no significant difference in CPS performance between boys and girls ($U = 38957.5$, $p = 0.053$). In the PISA framework (OECD, 2017), CPS skills are divided into four levels: Level 1 represents the lowest proficiency, Level 4 signifies the highest proficiency, and a level below Level 1 is characterized by a deficiency in these skills. Based on the definitions in the PISA framework, we distinguished students' CPS skills at different levels (see Figure 2). The distribution of students' skills in both countries exhibited a higher concentration in the middle levels and fewer at the extremes. The highest percentage of Chinese students at level 3 is 47.95%, while the highest percentage of German students at level 2 is about 45.36%. The percentage of German students at Level 1 and below Level 1 was higher than that of Chinese students.

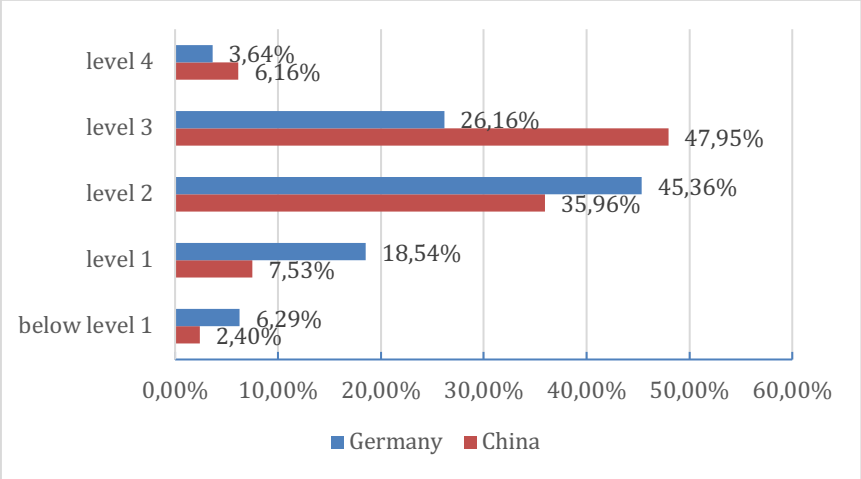

Figure 2. CPS Levels of students in two countries

To explore factors contributing to these differences, Pearson correlation coefficients were computed to assess the linear relationship between CPS and various factors (see Table 1). In both countries, cognitive ability and prior knowledge were positively correlated with students' CPS skills, while stress showed a negative correlation. For German students, interest and motivation were also positively correlated with CPS skills. Among these factors, cognitive abilities had the highest correlation coefficient in both countries.

Table 1. The Correlation of factors with CPS skills

		Country	Cognitive ability	Prior knowledge	Motivation and interest	Mental load and effort	Stress
CPS theta	Pearson Correlation	Germany (N= 302)	.310**	.142*	.238**	.084	-.349**
	Sig. (2-tailed)		.000	.014	.000	.147	.000
	Pearson Correlation	China (N = 292)	.459**	.362**	-.020	-.016	-.159**
	Sig. (2-tailed)		.000	.000	.735	.787	.007

Conclusion and discussion

In summary, there were differences in CPS skills between Chinese and German students, with Chinese students performing better than German students. Cognitive ability and prior knowledge are also two important factors that affect CPS skills and are positively correlated with CPS performance. As the complexity of collaboration increased, students performed worse in collaboration. Limitations of this study are the small sample size and small number of schools, which may impact the generalizability of the results.

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