The Development of Students' Collaborative Problem Solving Competency: A Survey Research

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Abstract
Collaborative Problem Solving (CPS) competency refers to the ability to collaborate with others by sharing knowledge, skills, and effort to solve a problem. CPS competency assesses students' ability to solve problems through communication and collaboration, focusing on three competencies; (1) establishing and maintaining shared understanding, (2) taking appropriate action to solve the problem, and (3) establishing and maintaining group organization. This study aims to explore the collaborative problem-solving competency of 43 students using the PISA 2015 online assessment, which consists of 12 questions with a total score of 24 points. The statistics were used to analyze quantitative data using percentages and averages. The researcher analyzed students' scores using the PISA 2015 criteria, classifying the results into three levels: high, moderate, and low level. The students achieved an average CPS score of 16.07, which represents 66.96%, indicating a moderate level of competency. Moreover, an analysis of sub-competencies revealed that students excelled in establishing and maintaining shared understanding, with an average score of 73.55%, indicating a high level of competency. However, their competency in taking appropriate action to solve problems (65.70%) and in establishing and maintaining group organization (61.63%) was at a moderate level. In summary, the researcher recognizes that students' collaborative problem solving competency can be developed and that students should be provided with opportunities to enhance their collaborative problem solving skills to reach a high level.

Keywords: Collaborative Problem Solving, Chemistry Education, Collaborative Education

Introduction

In the present era, economic, social, and cultural transformations, along with advancements in science and technology, necessitate that individuals adapt to evolving contexts to address the challenges of the 21st century. Education serves a crucial role in equipping students with essential skills, including innovation, creativity, teamwork, and problem-solving. The increasing demand for diverse and high-quality skills presents challenges for their future. The concept of 21st-century skills has gained prominence, reflecting both shifting workplace demands and the evolving role of education (Intelligence Unit, 2015). The 21st-century framework provides strategies for identifying the skills that students must develop to thrive in the workforce of future (González & Ramírez, 2022).

The rapid advancements in science and technology, globalization, and increasing complexities in social structures are reshaping dynamics in the economy, politics, and environment, while also transforming the organization and practice of science. Science education is considered a crucial component of the knowledge economy and intellectual progress, particularly in developing societies, due to the growing significance of science and technology. As a result, schools have placed greater emphasis on science-related subjects (Bal, 2018).

Although, science education is essential for equipping young people with the knowledge and skills needed to address these challenges (Bybee, 2010). The current science education lacks the necessary direction and foundational support to foster students' ethical values and inner principles, which are vital for their personal growth (Chowdhury, 2016). In present day, most students' learning involves collaboration with classmates in group activities. As a result, problem-solving skills are essential for life, improving both university education and work efficiency. Science education in the 21st century requires students to develop essential skills to succeed in an era of uncertainty and rapid, continuous change (Greiff et al., 2013). Chemistry is another subject that often involves learning activities related to visual skills and problem-solving. Teaching and learning in chemistry will incorporate various problem-solving approaches, such as hypothesis formulation, experimentation, data analysis, and the application of different theories. In the field of chemistry, it is essential for individuals to collaborate, leveraging shared knowledge and skills to address problems within a chemical context (Ying & Tiemann, 2024). In most chemistry classes in Thailand, teachers continue to rely primarily on lecture-based instruction and emphasize problem-solving, which limits students' development of both problem-solving and teamwork skills. The main issue is that some students do not actively participate in group work, resulting in a lack of essential problem-solving and teamwork skills needed for their future careers. This highlights the importance of fostering collaborative problem-solving competencies.

Collaborative problem-solving (CPS) has become a crucial component of today's knowledge and innovation-driven economy and society. As a result, communication and collaborative problem solving are considered essential 21st-century skills and have a significant impact on education, policy, and research. It also represents an integration of essential contemporary skills, as humans need collaborative problem-solving abilities to thrive in new environments. With the rapid advancement of technology, these skills enable individuals to adapt and apply collaborative problem-solving across various contexts. However, collaboration is becoming increasingly important as knowledge-based tasks are now performed more often by teams with complementary skills and expertise, rather than by individuals working alone in industrial settings (Autor et al., 2003). Moreover, collaborative problem-solving is an essential skill that enhances work efficiency and contributes to the modern global economy (Fiore et al., 2018). Complex problems often require multiple sources of information to find a solution. As a result, collaborative problem-solving has become a widely used and effective approach in the 21st century (Unal & Cakir, 2021). PISA 2003 defines problem-solving as the ability to apply cognitive processes to address real-life, cross-disciplinary challenges where the solution is not immediately apparent (OECD, 2003). PISA defines collaborative problem-solving as an individual's ability to actively engage in a process where multiple agents collaborate by sharing knowledge, skills, and efforts to solve a problem. PISA 2015 emphasizes task-oriented activities that require group processes, which cannot be completed by an individual alone. It highlights the importance of all members sharing their understanding and fully contributing their efforts (Graesser, 2020). Collaborative problem solving consists of three competencies that overlap with four problem-solving processes, resulting in a total of 12 skills (Webb & Gibson, 2015). The assessment of collaborative problem-solving competence includes three major competencies: 1) Establishing and maintaining shared understanding, identifying which group members possess the most knowledge about the problem and effectively sharing that information, 2) Taking appropriate action to solve the problem, determining the necessary actions to resolve the problem, 3) Establishing and maintaining team organization, managing one's role in the problem-solving process, ensuring that others fulfill their responsibilities, and making adjustments to enhance overall performance (OECD, 2017a). These core competencies integrate both collaboration and individual problem-solving processes (OECD, 2017b). The assessment of collaborative problem-solving competence revealed that Thailand's average score was 436, which falls below the standard average of 500 (OECD, 2017b). This suggests that Thai students still need to develop

teamwork skills, highlighting the importance of collaborative problem-solving for future careers and effective problem-solving in the modern workforce. Some of the research findings also indicate a lack of collaborative problem-solving competency, as students demonstrate low levels of social interaction and communication (Li et al., 2023). Additionally, students tend to avoid conflicts during collaborative activities, which results in restricted communication and knowledge exchange (Tehrani & Yamini, 2020). The researcher aims to investigate students' collaborative problem-solving competencies to analyze and identify ways to enhance these skills.

Methodology

Sample Group

The sample group was selected through voluntary participation in the assessment, comprising 43 grade 10 students.

Data Collection

The researcher assessed the collaborative problem-solving competency by using the PISA 2015 collaborative problem-solving competency assessment, which was based on an online test. The test consisted of 12 questions, which are multiple-choice questions. The maximum score is 24 points. The test assessed in 3 major competencies:

1) Establishing and maintaining shared understanding: these competencies are reflected in communication, as students share their insights and understanding with team members. It consists of four sub-competencies:

Aspect 1.1: Discovering perspectives and abilities of team members.

Aspect 1.2: Building a shared representation and negotiating the meaning of the problem.

Aspect 1.3: Communicating with team members about the actions to be/being performed.

Aspect 1.4: Monitoring and repairing the shared understanding.

2) Taking appropriate action to solve the problem: These competencies demonstrate students' ability. It consists of four sub-competencies:

Aspect 2.1: Identifying appropriate problem-solving approaches.

Aspect 2.2: Identifying and describing tasks to be completed.

Aspect 2.3: Enacting plans.

Aspect 2.4: Monitoring results of actions and evaluating success in solving the problem.

3) Establishing and maintaining group organization: These competencies illustrate how students organize problem-solving groups by considering members' abilities and roles. They follow guidelines, monitor group dynamics, reflect on effectiveness, and manage communication issues and conflicts. It consists of four sub-competencies:

Aspect 3.1: Understanding roles to solve the problem.

Aspect 3.2: Describing roles and team organization (communication protocol/rules of engagement).

Aspect 3.3: Following rules of engagement (e.g. prompting other team members to perform their tasks).

Aspect 3.4: Monitoring, providing feedback, and adapting the team organization and roles.

Data Collection and Data Analysis

In data collection, the researcher scheduled appointments and provided a detailed explanation to the students, ensuring they understood the objectives and the entire process before allowing them to voluntarily decide whether to participate in the assessment. Upon completion of the assessment, the researcher carefully reviewed the students' responses and computed their scores as percentages. These scores were then compared to the PISA 2015 assessment criteria, as presented in Table 1.

Table 1 The scoring criteria for the collaborative problem-solving competency assessment (OECD, 2017b)

Level	Low	Moderate	High
Score (%)	0 - 33	34 - 66	67 - 100

From Table 1, the three levels of criteria can be explained as follows:

High level referred to students contributing by sharing and clarifying essential information that shapes group dynamics, selecting effective processes to achieve objectives, and actively participating in problem-solving and situational management.

Moderate level referred to students actively engaging by requesting, sharing, and clarifying

essential information that shapes group operations. They effectively select processes to achieve shared goals and fulfill their assigned roles and responsibilities.

Low level referred to students' research and generate relevant information for their tasks, which helps clarify their roles and responsibilities. However, their contributions have a limited impact on the successful achievement of the group's objectives.

Results

The results indicated that 25 students are in the high level, 14 students are in the moderate level, and 4 students are in the low level. As shown in Figure 1.

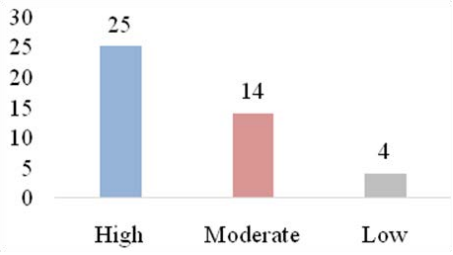

Figure 1 The Number of Students in Each Level

Additionally, the researcher analyzed the students' overall average score, which was 16.07, representing 66.96%, indicating a moderate level. Further analysis of the average scores for each aspect revealed that: 1) Establishing and maintaining shared understanding had an average score of 5.88 (73.55%), indicating a high level; 2) Taking appropriate action to solve the problem had an average score of 5.26 (65.70%), indicating a moderate level; and 3) Establishing and maintaining group organization had an average score of 4.93 (61.63%), indicating a moderate level, as shown in Figure 2.

Figure 2 The Percentage of Collaborative Problem-Solving Competency Scores of Students

Furthermore, the researcher conducted a detailed analysis of the scores across the sub-aspects of CPS competencies for each student, with the findings presented in Table 2.

Table 2 The Analysis of the Collaborative Problem-Solving Competency Scores of 43 Students

Students	Competency 1				Competency 2				Competency 3				Total (24)	%	Interpretation
	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4			
1	1	1	1	0	0	1	1	0	0	1	1	0	7	29.17	low
2	1	1	1	1	1	1	1	0	1	1	1	1	11	45.83	moderate
3	1	1	2	2	1	2	2	1	1	2	2	0	17	70.83	high
4	1	2	2	1	1	1	2	1	1	1	2	1	16	66.67	moderate
5	1	2	2	2	1	2	2	1	2	2	2	1	20	83.33	high
6	2	1	2	1	1	2	2	1	1	1	2	1	17	70.83	high
7	1	1	2	1	1	2	1	1	1	1	2	0	14	58.33	moderate
8	2	1	1	1	1	1	2	0	1	1	1	1	13	54.17	moderate
9	1	2	2	2	1	2	1	1	1	2	2	1	18	75.00	high
10	1	0	1	1	1	0	1	0	1	1	0	0	7	29.17	low
11	1	2	1	1	0	1	1	0	1	1	1	1	11	45.83	moderate
12	0	1	1	1	1	1	1	0	1	1	1	0	9	37.50	moderate
13	1	2	2	1	1	2	2	1	1	2	2	1	18	75.00	high
14	1	1	2	0	1	2	1	1	1	2	1	1	14	58.33	moderate
15	2	2	2	2	2	2	2	1	2	1	2	1	21	87.50	high
16	2	2	2	2	2	2	2	1	2	2	2	1	22	91.67	high
17	1	2	2	1	0	1	1	0	1	1	0	0	10	41.67	moderate

18	1	1	1	0	1	1	1	0	0	1	1	0	8	33.33	low
19	2	2	2	1	1	2	2	1	2	2	2	1	20	83.33	high
20	2	2	2	2	2	2	2	1	2	2	2	1	22	91.67	high
21	1	1	1	2	0	1	1	0	1	1	1	1	11	45.83	moderate
22	1	2	2	1	1	2	1	1	0	1	1	0	13	54.17	moderate
23	2	1	2	2	1	2	2	2	2	1	2	1	20	83.33	high
24	2	1	2	1	2	1	2	2	2	2	2	2	21	87.50	high
25	2	1	2	2	1	2	2	1	1	1	2	1	18	75.00	high
26	2	1	2	1	2	2	2	1	1	2	2	1	19	79.17	high
27	1	1	1	0	1	1	1	0	1	1	1	0	9	37.50	moderate
28	1	2	2	2	1	2	2	2	2	2	2	1	21	87.50	high
29	1	2	2	2	2	2	2	1	2	2	1	1	20	83.33	high
30	1	2	2	1	1	2	1	1	1	1	1	0	14	58.33	moderate
31	2	1	1	2	2	1	1	1	0	1	1	0	13	54.17	moderate
32	1	0	1	1	1	1	1	1	1	1	1	0	10	41.67	moderate
33	2	2	2	2	2	2	2	1	2	2	1	1	21	87.50	high
34	2	2	2	2	2	1	2	2	2	2	2	2	23	95.83	high
35	2	2	2	1	1	2	2	1	1	2	2	1	19	79.17	high
36	2	2	2	1	1	2	2	1	1	2	2	2	20	83.33	high
37	2	2	2	1	2	2	2	1	1	2	2	1	20	83.33	high
38	1	2	2	1	1	2	2	1	1	2	2	1	18	75.00	high
39	1	2	2	1	2	2	2	1	2	1	1	1	18	75.00	high
40	1	2	2	1	1	2	2	2	2	2	2	1	20	83.33	high
41	2	2	2	1	1	2	2	1	1	2	2	1	19	79.17	high
42	1	2	2	2	2	2	1	1	1	2	2	0	18	75.00	high
43	1	2	1	1	1	1	1	1	0	1	1	0	11	45.83	low
Mean	1.37	1.53	1.72	1.26	1.19	1.60	1.58	0.88	1.19	1.49	1.51	0.74	16.07		

The average score for the first competency, establishing and maintaining shared understanding, revealed that students scored highest in Aspect 1.3, with an average of 1.72, indicating active exchange of information and problem-solving methods within their groups. This was followed by Aspect 1.2, with an average score of 1.53, and Aspect 1.1, with an average score of 1.37. The lowest score was observed in Aspect 1.4, with an average of 1.26, suggesting relatively low engagement in verifying their shared understanding of the problem within the group.

The average score for the second competency, taking appropriate action to solve the problem, revealed that students scored highest in Aspect 2.2, with an average of 1.60, indicating their ability to clearly define and explain their responsibilities within the group. This was followed by Aspect 2.3, with an average of 1.58, and Aspect 2.1, with an average score of 1.19. The lowest score was in Aspect 2.4, with an average of 0.88, suggesting relatively low engagement in reviewing errors or assessing the outcomes of their group's problem-solving process.

For the third competency, establishing and maintaining group organization, students scored highest in Aspect 3.3 (1.51), indicating effective adherence to responsibilities and group rules. This was followed by Aspect 3.2 (1.49) and Aspect 3.1 (1.19). The lowest score was in Aspect 3.4, adapting team organization and roles, with an average of 0.74, suggesting low engagement in evaluating or improving group processes.

When considering the number of students by competency level for Competency 1: establishing and maintaining shared understanding, the data is presented in Figure 3.

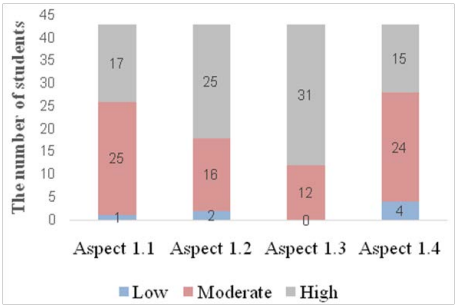

Figure 3 The Number of Students in each Level of Competency 1

As shown in Figure 3, the number of students at the high competency level was highest in Aspect 1.3, followed by Aspect 1.2, Aspect 1.1, and Aspect 1.4, with 31, 25, 17, and 15 students, respectively.

The distribution of students by competency level for Competency 2: taking appropriate action to solve the problem is presented in Figure 4.

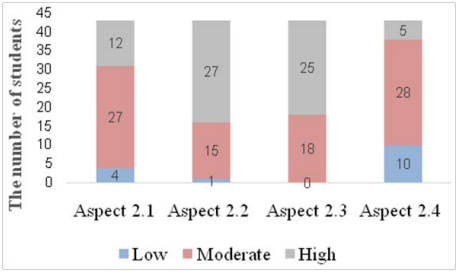

Figure 4 The Number of Students at Each Level of Competency 2

Figure 4 illustrates that the highest number of students at the high competency level was in Aspect 2.2, followed by Aspect 2.3, Aspect 2.1, and Aspect 2.4, with 27, 25, 12, and 5 students, respectively.

The researchers analyzed students' scores for the third competency, establishing and maintaining group organization, using the scores for each aspect to classify students into different levels, as shown in Figure 5. Figure 5 shows that the highest number of students at the high competency level was in Aspect 3.3, followed by Aspect 3.2, Aspect 3.1, and Aspect 3.4, with 24, 21, 13, and 3 students, respectively.

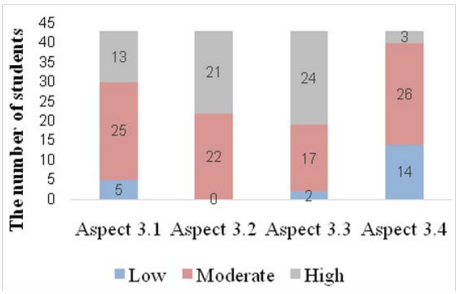

Figure 5 The Number of Students at Each Level of Competency 3

Conclusion and Discussion

The research findings indicate that students' collaborative problem solving competency has an average score of 16.07, representing 66.96%, indicating a moderate level. This suggests that students actively participate in teams but struggle with taking initiative and tackling complex problems. They respond to requests and prompts, selecting actions that support group objectives. However, they hesitate to initiate actions independently and face challenges with conflict resolution, adaptation, and overcoming obstacles to their goals. Meanwhile, Education in Thailand focuses on developing students' skills for the labor market while also equipping them with essential 21st-century skills to succeed in an era of uncertainty and rapid change. In Thailand, traditional lecture-based teaching and inquiry-based learning are still commonly used in secondary school science classrooms (Jantarakantee, 2016). Thai traditional culture discourages students from openly sharing opinions that contradict their teachers or peers (Songsil et al., 2019). The Thai education system remains largely teacher-centered, with lectures being the primary instructional method (Loima, 2016). This approach limits students' opportunities for self-directed learning and reduces their active participation in the learning process. In Thai culture, students are taught to show respect, which often leads to reluctance to ask questions during learning. This is further reinforced by the educational system, which encourages a passive role for students and instills a fear of questioning. Consequently, this cultural and educational environment in Thailand discourages students from seeking clarification. Many students avoid drawing attention

to themselves or disrupting the class by asking questions during the lesson (Phoewhawm, 2019). Furthermore, Thai students tend to prefer solving problems independently and are reluctant to share their opinions or collaborate with peers (Maniam & Pruekpramool, 2019). Consequently, most students lack problem-solving and teamwork skills, which are essential for their future careers. Subsequently, the researcher analyzed the scores for each aspect of the competencies and found that students achieved the highest competency in establishing and maintaining shared understanding, with an average score is 5.88, which accounts for 73.55%, indicating high level. This shows that students can identify problems, gather relevant knowledge, and seek information to develop a comprehensive understanding appropriate to the context. Additionally, they recognize knowledgeable group members and effectively share information within the team. They effectively aligned their knowledge with peers, engaged in meaningful discussions, and evaluated their problem-solving strategies, fostering successful collaboration (Capraro et al., 2013). This is consistent with a study by Yavuz & Atar (2020), which found that Taiwanese students find the skill of "establishing and maintaining shared understanding" easier than the other two competencies. Subsequently, taking appropriate action to solve the problem competency, with an average score is 5.26, which accounts for 65.70%, placing it at a moderate level. This demonstrates that students establish goals for problem-solving and collaboratively plan solutions that align with their context. They can also identify problem-solving strategies through group collaboration that relate to their specific situations. Students participated in discussions to choose methods, exchanging views to thoughtfully determine the most appropriate and effective approach. Referred to Kuo et al. (2019) determined that the most difficult competency for Taiwanese students was "taking appropriate action to solve the problem". The lowest score competency was establishing and maintaining group organization, with an average score is 4.93, which accounts for 61.63%, placing it at a moderate level. This indicates that students can effectively adhere to the group's agreements, aligning their roles with the situations they encounter. They are capable of reporting problems related to their work and collaborating to plan or adjust roles when issues arise or when actions deviate from the established plan. Students identified roles and responsibilities, assigned tasks, provided feedback, and occasionally adjusted group roles. This is in line with the study conducted by Li and Liu (2017), examined collaborative problem-solving (CPS) skills in scientific contexts and found that Taiwanese students demonstrated proficiency across all 11 CPS skills. In line with Burns et al. (2014) stated that collaborative problem-solving skills can be developed in learners. By working together in a social environment, students can construct knowledge, solve problems, and effectively create group projects. In line with Pruner et al. (2021), it is suggested that students communicate more effectively when they explore a wider range of information sources. Although perceptions of collaborative problem-solving skills may vary across countries, their development remains essential. Students learn more effectively in environments that encourage idea exchange and discussion (Kutluca, 2013). The results of this study explore the collaborative problem-solving competencies of students in the context of Thailand. The researcher aims for this study to provide supplementary information for enhancing students' collaborative problem-solving competency. The research results indicate that while some sub-competencies of students are at a high level, most remain at a moderate level. Therefore, the researcher suggests developing students' collaborative problem solving competencies through diverse teaching approaches to achieve a high level. This is consistent with the research of Gu et al. (2015), found that preventive structural learning enhanced students' collaborative problem-solving competencies. According to Lin et al. (2020), a web-based collaborative problem-solving system, combined with teacher guidance, can enhance junior high students' collaborative problem-solving skills in STEM education. Furthermore, research indicates that the design of instructional activities, combined with Technological Pedagogical Content Knowledge has a significant impact on students' learning outcomes (Sonsupap et al., 2024). Therefore, teachers should develop a deep understanding of the instructional context and

design learning experiences that foster collaborative problem-solving while simultaneously enhancing other learning achievements. Future research should investigate students' collaborative problem solving competencies using different teaching methods in various contexts to enhance in taking appropriate action to solve the problem and establishing and maintaining group organization competency and achieve high level. Additionally, it may be necessary to include observations of students' collaborative behaviors to explore their collaborative problem-solving competency through hands-on practice. A key finding of this study highlights the influence of parenting culture, societal factors, and the learning environment on collaborative problem-solving competency. A comprehensive analysis of these relationships is crucial for developing a deeper understanding, enabling the strategic design and implementation of learning activities that effectively foster and enhance collaborative problem-solving development in the future.

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