IDENTIFICATION OF SOCIAL AND COGNITIVE DOMAIN CRITERIA ‘KEYWORD’ ON COLLABORATIVE PROBLEM SOLVING SKILLS ANALYTIC RUBRIC

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ABSTRACT

The development of science and technology in the 21st century give impacts on various fields, one of which is education. The main focuses of these educational goals are 21st-century skills demands. One of the skills that must have is the collaborative problem-solving skill (CPS). However, this CPS is still facing constraints for teaching practitioners. Therefore, this research aims to develop CPS instruments through questions item that needs to be solved holistically from various disciplines such as STEM. One of the processes carried out in the development of this assessment instrument is determining the “keywords” social and cognitive domain criteria contained in the CPS analytic rubric. The developed instrument was a computer-aided instrument using the principle of collaboration agent. The ‘keyword’ validation process is limited to 6 practice samples. The conversation history on finding the solution for the specific practice samples is recorded in the developed database. Further, these data followed the similarity protocol producing each participant score and exported as necessary for analysis purposes. The analysis shows that determining these ‘keywords’ still needs further refinement and validation. Further research, the sample of the participant should be more substantial and coverage many regions in Indonesia to enrich keywords so that the instrument could be used nationally.

KEYWORDS  
CPS, keyword criterion, STEM, collaborative agent.

1. INTRODUCTION

The comprehension of the 21st century and the industrial revolution 4.0 (IR 4.0) skills within education setting have heightened the need for Indonesia National Education to portray 16 skills of the 21st century skills (World Economic Forum, 2015) and top 10 IR 4.0 skills (Mohd Kamaruzaman, Hamid, Mutalib, & Rasul, 2019) within the curriculum. In the area of these skills, collaboration together with critical problem solving, creativity, and communication are four skills that made up the competency’s component of the 21st-century skills, that is how students approach complex challenges. Complex problem solving and creativity skills are two skills that contained within the learning and innovation skills of the IR 4.0. Likewise, teamwork and collaboration skill, interactive communication, and personal and social responsibility are three skills that come from effective communication skills of IR 4.0. Altogether, they construct the necessary skills required for collaborative problem solving (CPS).
CPS has two main areas i.e., the collaborative (communication or social aspects) and the knowledge or cognitive aspects (domain-specific problem-solving strategies) (Fiore et al., 2017). CPS is increasingly recognized as one of the 21st-century skills, especially related to science, technology, engineering, and mathematics (STEM). Griffin & Care (2015) define CPS as approaching a problem responsively by working together and exchanging ideas. CPS is particularly useful when dealing with complex problems. Collaboration is a useful tool, especially when specific expertise is needed and relies on factors such as a readiness to participate, mutual understanding, and the ability to manage interpersonal conflicts. In the meantime, CPS for PISA 2015 is articulated as “The capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills, and efforts to reach that solution” (OECD, 2015). Nowadays, students entering the workplace and public life are expected to have CPS skills and also the ability to collaborate in various group compositions and environments (Patrick Griffin, McGaw, & Care, 2012).

Care & Griffin (2014) study outlines the process of creating definitions for evaluating a set of CPS skills while gives an overview of the elements of each domain, as shown in Table 1. The study illustrates how CPS leads to the development of learning, which is hypothesized to illustrate that skills may vary in increasingly proficient individuals. In the process of developing CPS assessments, assignments are reviewed in terms of how they can reflect constructs and how they can engage students so that their thought processes can be captured, coded, assessed, and interpreted. The study concluded that the assessment approach taken could be applied in schools. The 21st-century education must be centered on knowledge, so students can move beyond current understanding to negotiate life in a dynamically changing world; needs to be centered on students where students are actively involved; community-centered so that knowledge development is collaborative; and center on assessment so progress can be monitored.

| Collaborative Skills Domain | Problem Solving Skills |
|----------------------------|------------------------|
| **Element** | **Skills assessed** | **Element** | **Skills assessed** |
| Participation | Action | Task regulation | Problem analysis |
| | Interaction | | Goal setting |
| | Task completion | | Resource management |
| | | | Flexibility and ambiguity |
| Perspective Taking | Adaptive responsiveness | Knowledge building | Data collection |
| | Audience awareness | | Systematic problem solving |
| Social Regulation | Negotiation | Relationship | Hypotheses |
| | Self-evaluation | | |
| | Transactive memory | | |
| | Responsibilities initiative | | |

Source: modified from (Care & Griffin, 2014)

Further study, (Lin et al., 2015), developed a STEM-based assessment system to evaluate CPS skills of junior high school students. The primary theoretical basis for designing the CPS learning objectives is the CPS matrix proposed by the OECD using eight assessment modules in STEM education. Three specialists were invited to check the content validity of the developed eight modules and tested by 222 Taiwanese junior high school students. The results obtained are inter-correlation of student performance in each assessment module concerning overall and each three CPS skills. These CPS skills are building and maintaining mutual understanding, taking appropriate actions to complete problems, and building and maintaining team organizations. Many studies described the use of a software agent as an agent program that operates in parallel with the user. One of the researches related to the design and implementation of agents is animation-based pedagogical agents (Johnson & Lester, 2016) that used in the learning environment as virtual trainers. Studies in educational technology have focused on the use of pedagogical agents while students are learning. Pedagogical
Agent in the form of animated characters that guide and encourage students in computer-based learning, interact with students utilizing simulating human.

CPS in this study is about working together in an online workspace focusing on problem-solving in a real-world context. When collaborating, questions, and arguments often arise that eventually requiring simulations to create mutual understanding. It necessitates various skills and understanding as well as the use of various tools and application of various learning methods for solving the problems encountered. The purpose of this study is to produce a CPS assessment instrument to enable assessment holistically on student skills in understanding and practicing collaborative activities. Hence, researchers developed CPS blueprint and assessment instrument that can be used as the teacher's guide in evaluating students’ CPS skills on various subjects of the 2013 National Curriculum. It is hoped that this research assists teachers in motivating students to pursue collaborative skills, which are the 21st Century skills that students must have in the era of IR 4.0. Further, it is hoped that students will gain a better understanding of science, mathematics, and reading literacy and performing better at the future PISA competencies test.

2. METHODOLOGY

The main goal of this qualitative research is to produce a prototype of the blueprint of CPS assessment instrument that reveals social and cognitive domains along with its analytic rubrics and associated indicators and keywords for the assessment of the CPS skills purposes. In order to achieve the goal, the study carries out an examination of instrument validity and piloting instrument results. The study starts with requirement analysis of the 2013 curriculum for underlying competencies context that needs collaborative problem-solving approaches. Further, we develop three CPS questions each for junior and senior high school, including its problem indicator about a particular CPS question. In this study, each CPS question has a different level of difficulties, ranging from easy, moderate, and complex. Next, the study carries out the design and development of social domains (collaborative skills) and cognitive domains (problem-solving skills) assessment instrument. The CPS assessment is measured using developed rubrics as depicted in Figure 1. Finally, the validation process is carried out by testing the instruments by senior high school teachers acting as experts (practitioners). The teachers scrutinize the content of the CPS questions and then assess the rubrics for validation using the provided validation form. The teachers’ respondents are from the city and district area in Bandung West Java Indonesia. The validation instrument use on Care and Griffin blueprint, who used it as a guide to test indicators in terms of the type of behavior hypothesized (Table 2) as an approach to doing the task.

![CPS Assessment Diagram](image)

![Rubrics of the CPS Assessment Table](image)

Figure 1. The design of analytic rubrics and keywords development
Table 2. Section of the blue print for Task Regulation

| Element                  | Indicator                                                                 | Low Level                                                                 | Middle Level                                                                 | High Level                                                                 |
|--------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Organizes (problem analysis) | Analyses and describes a problem in familiar language                     | Problem is stated as presented in ambiguous situations                    | Problem is divided in subtasks and suggest action                          | Identifies necessary sequence of subtasks and explores options            |
| Flexibility and ambiguity | Accept ambiguous situation                                                | Inaction in ambiguous situations                                           | Notes ambiguity and suggest action                                        | Systematically exhausts possible solutions                                |
| Systematicity             | Implements possible solutions to a problem and monitor progress           | Trial and error actions                                                   | Purposeful sequence of actions                                             |                                                                            |

Source: Care and Griffin, 2014

3. RESULT AND DISCUSSION
3.1 Requirement analysis for CPS questions

The most challenging tasks in adapting CPS on the National Curriculum is analyzing the inherent base competencies of each course in order to develop proper CPS questions. This study uses three CPS questions for senior high school (Table 3). The study uses physics, biology, and chemistry subjects as the substance on developing the CPS questions. Figure 3(a) depicted sample of Physics CPS question for grade X, Figure 3(b) Biology CPS question for grade XI, and Figure 3(c) Chemistry CPS question for grade X.

![Figure 3. Sample questions of (a) Physics CPS question for grade X, (b) Biology CPS question for grade XI, and (c) Chemistry CPS question for grade X](image-url)

Table 2. Section of the blue print for Task Regulation

| Element                  | Indicator                                                                 | Low Level                                                                 | Middle Level                                                                 | High Level                                                                 |
|--------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|
| Organizes (problem analysis) | Analyses and describes a problem in familiar language                     | Problem is stated as presented in ambiguous situations                    | Problem is divided in subtasks and suggest action                          | Identifies necessary sequence of subtasks and explores options            |
| Flexibility and ambiguity | Accept ambiguous situation                                                | Inaction in ambiguous situations                                           | Notes ambiguity and suggest action                                        | Systematically exhausts possible solutions                                |
| Systematicity             | Implements possible solutions to a problem and monitor progress           | Trial and error actions                                                   | Purposeful sequence of actions                                             |                                                                            |

Indicator: Applying the concept of parabolic motion through everyday events

Question: A rugby sports striker prepares to kick the ball from an 18-meter line, the height of the ball from the ground is 1 meter. If the striker kicks the ball with an angle of 55 degrees to the horizontal (ketinggian ini melebihi ketinggian gawang, maka bola tersebut akan melewati gawang, namun hal ini tidak mungkin dilakukan karena terlalu tinggi)

If the given angle is more than 55 then the height of the ball will exceed the goal height, then the ball will pass the goal.

Example: If the angle of 55 degrees is more than 55, then the height of the ball exceeds the goal height, then the ball will pass the goal.

To determine the genetic code of an individual's characteristics, Based on the horizontal parabolic motion equation:

\[ y = x \tan \theta - \frac{g}{2v^2 \cos^2 \theta} x^2 \]

Where:
- \( y \) is the height of the ball when reaching the goal
- \( x \) is the horizontal distance from the goal
- \( \theta \) is the angle of the initial speed and elevation angle of the ball
- \( g \) is the acceleration due to gravity (9.8 m/s^2)
- \( v \) is the initial speed of the ball

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If the height exceeds the goal height, then the ball will pass the goal.

Based on the proton, electron, and neutron data, make a group of elements based on the characteristics of the atomic nucleus they have.

| Element | Name | Isobar | Name |
|---------|------|--------|------|
| 1H | Hydrogen (H) | 1| Hydrogen (H) |
| 6Li | Lithium (Li) | 6| Lithium (Li) |
| 12Mg | Magnesium (Mg) | 12| Magnesium (Mg) |
| 16S | Sulfur (S) | 16| Sulfur (S) |
| 32S | Sulfur (S) | 32| Sulfur (S) |
| 56Fe | Iron (Fe) | 56| Iron (Fe) |
| 232Th | Thorium (Th) | 232| Thorium (Th) |

Based on the proton, electron, and neutron data, make a group of elements based on the characteristics of the atomic nucleus they have.

| Isotope | Name | Isobar | Name |
|---------|------|--------|------|
| ^{1}H | Hydrogen (H) | 1| Hydrogen (H) |
| ^{6}Li | Lithium (Li) | 6| Lithium (Li) |
| ^{12}Mg | Magnesium (Mg) | 12| Magnesium (Mg) |
| ^{16}S | Sulfur (S) | 16| Sulfur (S) |
| ^{32}S | Sulfur (S) | 32| Sulfur (S) |
| ^{56}Fe | Iron (Fe) | 56| Iron (Fe) |
| ^{232}Th | Thorium (Th) | 232| Thorium (Th) |

Isotope: atoms of the same element that have the same atomic numbers (Z) and the number of protons Z.

So, the answer: ^{40}Ca, ^{40}Ti, ^{40}Ca, and ^{40}Ti

Name: Calcium (Ca)

Isotopes: atoms that have the same mass numbers (A), but the atomic number (Z) is different.

So, the answer: ^{40}Ca, ^{40}Ti, ^{40}Ca, and ^{40}Ti

Name: Calcium (Ca)

Isotopes: atoms that have the same mass numbers (A), but the atomic number (Z) is different.

So, the answer: ^{40}Ca, ^{40}Ti, ^{40}Ca, and ^{40}Ti

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Isotopes: atoms that have the same mass numbers (A), but the atomic number (Z) is different.

So, the answer: ^{40}Ca, ^{40}Ti, ^{40}Ca, and ^{40}Ti

Name: Calcium (Ca)
Remind that, each CPS question has different adversity level, ranging from easy, moderate, and complex mimicking the Bloom taxonomy revision. In the developed CPS context, easy CPS question is analogous to application ability (C3), that is the ability of a person to apply or use general ideas, procedures or methods, principles, formulas, theories, in a new and concrete situation (Problem No. 3). Moderate CPS question is similar to evaluating ability (C5), Present and defend opinions by making judgments about information, the validity of ideas, or quality of work based on a set of criteria (Problem No. 2). Whereas the difficult CPS question is similar to creating ability (C6), that is Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions (Problem No. 1).

| CPS questions' Indicator                                                                 | Problem No.1                                      | Problem No.2                                      | Problem No.3                                      |
|----------------------------------------------------------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|
| Senior high school                                                                    | *Physics: Predict strategic solution related to the problem of parabolic motion in everyday life* | *Biology: Determine DNA prototype structure in determining the genetic code of individual characteristics* | *Chemistry: Identify Group elements according to their atomic nucleus characteristics* |

### 3.2 Validation of the CPS questions

The steps taken in developing an assessment instrument are determining whether the items developed thoroughly measure what we are going to measure. The developed CPS instrument consisted of grade IX and X problems, each with easy, moderate, and complex adversity levels. The initial stage carried out to determine the validity of the CPS question is to find information about the assessment using the CPS questionnaire measuring ten assessment aspects. For this reason, high school teachers are asked to rate the CPS validity questionnaire by filling in a Likert scale questionnaire. The total number of respondents for high school teachers are six persons, comprise of two teachers from high school Bandung City, and three teachers from Bandung district. The questionnaire was prepared based on seven elements of the assessment, and each aspect of the assessment has several descriptors. For no-1-3 element, the questionnaire was developed based on griffin blueprint (Table 4). It consisted of nine descriptors of all elements. The practitioner judged each descriptor by giving the score range 1-5. The criterion is that the higher the number, the better the descriptor mentioned.

| No. | Assessment Element | Descriptor                                                                                                                                 |
|-----|--------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| 1.  | Analysis of the problem | D1 Problems are expressed in easy-to-solve and straightforward forms  
D2 The problem is stated by dividing the problem into sub-tasks and can be solved align with the sub-tasks  
D3 Problems are stated in detail; therefore identification of the order of problem-solving is required  |
| 2.  | Flexibility and Ambiguity | D4 The problem presented does not require many choices of problem-solving strategies because no ambiguity but lacks flexibility  
D5 The problem presented has several choices of problem-solving strategies because it has ambiguity and flexibility  
D6 The problem presented requires tracking the selection of problem-solving strategies because it has high flexibility  |
| 3.  | Systematic problem solving | D7 The problem presented does not require a systematic solution, it can be solved by trial and error  
D8 The problem presented requires a systematic solution. It cannot be solved just by trial and error  
D9 The problem presented requires a systematic sequence in solving the problem so that it can be solved using several strategy choices |
Figure 4.a showed that some practitioner perceives problem no.1 as a problem that needs more identification and order in solving problem, and others perceive the given sub-tasks could solve the problem in sequent. Few of practitioner perceive it as a simple problem. It concluded that the problem No.1 is valid belonging to high-level criteria of Griffin (Table.2) as its design. It also acts on Problem No-3 that was designed as a low-level problem where most of the practitioners perceived in the same way. However, some practitioners perceive problem no.2 as the high-level problem that showed by the highest score (5) of D3. It is not in coherence with the designed criteria as a middle-level problem.

Figure 4.b described that problem no.1 has more flexibility and ambiguity than others. They judged it needs more effort in choosing the best strategy to solve the problem. Problem no.2 for descriptor D4 get it highest average score in 4.47 that means it does not have flexibility in solving the problem. In general, all problem’s judgment results for this element are in coherence with the designed criteria.

Figure 4.c supported the judgment result of the previous element. It explained that problem no.1 requires a systematic sequence in solving the problem so that it can be solved using several strategic choices. Besides, problem no.2 also requires a systematic solution, and it cannot be solved just by trial and error. At last, most practitioners perceive problem no.3 same as problem no.2. It is not in coherence with the problem design criteria.

To sum up, the average results showed that practitioners have several perceptions in judging each CPS question. However, in general, it is in coherence with the developed criteria.

After the validation process of element no.1 - 3, we conducted the reliability counting processes for element no. 4-7. Table 5 presents assessment aspects and its descriptor that measure the reliability of the developed CPS questions to conform to the national curriculum. Therefore, the respondents of the validation questionnaire are subject matter teachers in physics, biology, and chemistry.

Table 5. Assessment aspects and its descriptor to conform with the national curriculum

| No. | Assessment Aspect | Descriptor |
|-----|------------------|------------|
| 4.  | Relevance        | D10        |
|     |                  | D11        |
|     |                  | D12        |
|     |                  | D13        |
|     |                  | D14        |
|     |                  | D15        |
The reliability analysis results showed that the alpha coefficient (the Cronbach’s alpha) for CPS question No. 1, 2, and 3 for senior high school are consecutively .820, .824, and .813 (Table 6). The Cronbach’s alpha results suggesting that the descriptors have relatively high internal consistency, especially for the developed CPS questions. Note that a reliability coefficient of .70 or higher is considered acceptable in a most social science research situation.

| Problem No. | Cronbach’s Alpha | N of Items | Cronbach’s Alpha | N of Items | Cronbach’s Alpha | N of Items |
|-------------|------------------|------------|------------------|------------|------------------|------------|
| No. 1       | .820             | 24         | .824             | 15         | .813             | 24         |

The senior high school CPS questions gain high internal consistency indicated by the alpha coefficient of .820, .824, and .813 consecutively for CPS question No1, 2, and 3. The respondents consider that all CPS questions satisfy the descriptors of completeness of material under the level of student development (D13), an illustration of functional media that is sufficient (D15), and encourage students to build their knowledge (D21) (Table 7). However, there are 8 out of 15 descriptors were inconsistent in CPS question No. 1; there are 5 out of 15 descriptors were inconsistent in CPS question No. 2; and there are 9 out of 15 descriptors were inconsistent in CPS question No. 3. These means that senior high school CPS question No 1, 2, and 3 require improvement in terms of its relevancy, accuracy, completeness of presentation, and suitability of presentation with the demands of student-centered learning. One probable cause of these consistencies (corrected item-total correlations is less than .30) is mainly because the small number of teachers validated the questionnaire.

| Problem No.1 | Problem No.2 | Problem No.3 |
|--------------|--------------|--------------|
| Indicator    | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Cronbach's Alpha Mean if Item Deleted | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Cronbach's Alpha Mean if Item Deleted | Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Cronbach's Alpha Mean if Item Deleted |
| D10          | 89.67 140.267 | .000 61.000 36.500 | .833 .779 82.50 183.900 | - .054 .816 |
| D11          | 89.83 142.167 | -.212 58.190 49.700 | .571 .806 82.67 184.667 | - .084 .820 |
| D12          | 91.17 108.167 | .860 60.400 37.300 | .977 .759 82.83 180.967 | 0.080 .815 |
| D13          | 89.67 140.267 | .000 57.800 57.700 | .000 .829 82.64 183.900 | - .054 .816 |
| D14          | 91.83 99.767 | .891 58.400 46.300 | .526 .809 83.17 177.367 | - .276 .810 |
| D15          | 91.67 98.667 | .845 58.800 47.700 | .973 .788 83.67 170.667 | 0.435 .804 |
| D16          | 89.83 142.167 | -.212 58.200 49.700 | .571 .806 82.50 183.900 | - .054 .816 |
| D17          | 91.50 129.100 | .311 57.800 57.700 | .000 .829 85.67 143.467 | .954 .770 |
| D18          | 92.67 107.867 | .932 59.600 55.300 | -.012 .870 85.17 143.367 | .836 .774 |
| D19          | 89.67 140.267 | .000 58.400 56.300 | .134 .828 83.00 177.600 | .174 .813 |
| D20          | 89.83 142.167 | -.212 58.000 53.500 | .611 .813 82.50 183.900 | - .054 .816 |
| D21          | 90.00 144.400 | -.245 58.000 53.500 | .611 .813 83.17 171.367 | - .227 .814 |
| D22          | 89.83 142.167 | -.212 57.800 57.700 | .000 .829 84.50 149.500 | - .597 .791 |
| D23          | 89.67 140.267 | .000 58.200 52.700 | .591 .811 83.17 171.367 | - .227 .814 |
| D24          | 91.83 99.767 | .891 58.600 51.800 | .885 .805 85.17 143.367 | .836 .774 |

Note: Rel 11 - Rel 63: Relevance  L11-L13: Completeness of presentation  K11-K41: Accuracy  Ses11- Ses41: Suitability of the presentation
3.3 Development of CPS assessment

Collaboration is an activity where several people work together to achieve the same goal. There are several types of activities referred to in the definition above. One of the activities contained in collaboration is communication wherein there is an exchange of knowledge or opinions to optimize the recipient's understanding. While this is necessary, CPS requires a level of communication that is more than just the exchange of information. Each individual must be able to see things from several other people's perspectives and also present individual responses as a form of contribution. Other activities involve how to manage collaboration, namely the skills to work and participate with others. Collaboration is a conceptualization of social skills; in other words, collaboration is part of the social skills domain. Three elements are relevant to this social skill, that is, participation, perspective-taking, and social regulation.

Cognitive skills that are essential for successful collaborative problem solving are similar to those needed for individual problem-solving. It applies to how problem-solvers manage the task at hand and how someone uses their reasoning skills. Both the task regulation and knowledge building elements depend on reasoning skills with the assumption that reasoning can be taught. Therefore, the cognitive domain problem-solving skills become a significant thing, especially in collaborative problem-solving. The occurrence of reasoning can be seen throughout the inductive and deductive processes. Inductive reasoning focuses on finding patterns. Deductive reasoning focuses on understanding the implications of statements and rules of logic. There are two elements in the cognitive domain of problem-solving that is task regulation and knowledge building.

In this study, the CPS assessment is divided into four levels of capability, that are a beginner (level 1), emerging (level 2), intermediate (level 3), or advanced (level 4) with a given score of 1, 2, 3, and 4 consecutively. The developed rubrics for CPS assessment follow the level of assessment and related scores along with relevant indicators. A pair of students will generally give different responses. Therefore, each student's score will be unique (individual) even though the students are in the same group.

3.3.1 Social Domain Rubrics

Table 8 described the rubrics that are relevant to social domain skill, that is, participation, perspective-taking, and social regulation and its indicators. Cross-section of each CPS skill and each capability level have rubrics’ indicator accordingly. For instance, indicators for an intermediate level of participation skills are developed as “According to orders and requests” and “Students actively give respond to partners to solve the problems.”

Table 8. Developed rubrics for social domain CPS skills cross section with four level of student capability

| CPS Skill | Level 1: Beginner (score = 1) | Level 2: Emerging (score = 2) | Level 3: Intermediate (score = 3) | Level 4: Advance (score = 4) |
|-----------|-------------------------------|-------------------------------|----------------------------------|-----------------------------|
| a.        | Participation                 |                               |                                  |                              |
| Students do not participate in identifying problems, determining steps, and sharing tasks to solve the problems. Students do not communicate with partners to determine their respective tasks in solving the problems. | Students actively participate when given help/direction. Communication with partners only occurs at some times when something important happens. Students begin to be sensitive to partner | Students follow orders and requests. Students actively give respond to partners to solve the problems. | Students repeatedly participate in active discussions with partners to complete assignments and use various strategies before giving answers. Students can adjust their communication manner according to partners understanding and easily understand where to start working on the assignments. |
Communication that occurs is in the form of introductory communication only.

**Level 1: Beginner (score = 1)**
- Students are very responsive to partners; it takes a long time to answer the conversation.
- Students tend to ignore partner contributions.
- Students contribute to partners’ understanding.
- Students modify the way they communicate with partners to increase understanding with one another by sharing resources and information.
- Students combine contributions from partners to make new solution steps or corrected the wrong steps. They use solutions provided by partners and work collaboratively in the problem-solving process.
- Students assume group responsibility for task success.
- Students and partners can resolve conflicts successfully, resolving differences that arise before determining possible solutions.
- Students can evaluate their performance in doing the overall task.
- Students can evaluate partners’ strengths and weaknesses based on partners’ performance when working on the assignments.

**Level 2: Emerging (score = 2)**
- Students are not very responsive to partners; it takes a long time to answer the conversation.
- Students tend to ignore partner contributions.
- Students contribute to partners’ understanding.
- Students modify the way they communicate with partners to increase understanding with one another by sharing resources and information.
- Students assume group responsibility for task success.
- Students and partners can resolve conflicts successfully, resolving differences that arise before determining possible solutions.
- Students can evaluate their performance in doing the overall task.
- Students can evaluate partners’ strengths and weaknesses based on partners’ performance when working on the assignments.

**Level 3: Intermediate (score = 3)**
- Students tend to work individually without dissenting the responsibility in solving the problems.
- Students are informing partners about the activities they do while working on assignments.
- Students make comments or share information with partners about their performance.
- Students and partners try to have the same understanding of the related tasks.
- Students and partners try to resolve differences in understanding the problem but fail to achieve resolution on those differences.
- Students are aware of a partner’s performance and give comments and ask the progress of partners in working on assignments.

**Level 4: Advance (score = 4)**
- Students combine contributions from partners to make new solution steps or corrected the wrong steps. They use solutions provided by partners and work collaboratively in the problem-solving process.
- Students assume group responsibility for task success.
- Students and partners can resolve conflicts successfully, resolving differences that arise before determining possible solutions.
- Students can evaluate their performance in doing the overall task.
- Students can evaluate partners’ strengths and weaknesses based on partners’ performance when working on the assignments.

Source: Griffin & Care 2015

The participation element refers to someone's readiness to share and convey their thoughts and how they are involved in the collaboration. There are several skills in the participation element, namely, action, interaction, and task completion/perseverance. The perspective-taking element allows each individual to understand each other’s views and to modify or adapt their behavior based on the recognition of differences of opinion. There are two aspects of the elements of perspective-taking, that is adaptive responsiveness and audience awareness. The social regulation element provides facilities for individuals to realize and manage the problem space in terms of the implications of human behavior for it. Intra and interpersonal awareness are essential to optimize the strategic aspects of solving this collaborative problem. There are four skills involved in this element that are negotiation, self-evaluation, transactive memory, and responsibility initiative. Negotiation skills can be evidence of where differences between coworkers are being resolved.

### 3.3.2 Cognitive Domain Rubrics

Table 9 described the rubrics that are relevant to cognitive domain skill, that is task regulation and knowledge building and its indicators. Cross-section of each CPS skill and each capability level have rubrics’ indicator accordingly. For instance, indicators for advance level of task regulation skills are developed as “Students decide to choose important information related to the problem posed, so they can plan systematic strategies in solving problems.”

Table 9. Developed rubrics for cognitive domain CPS skills cross section with four level of student capability
The task regulation element refers to the skills needed to map the problem and the questions related to the problem, which include the resources or artifacts in it, and the processes that follow. There are six capabilities in task regulation element, namely problem analysis, goal setting, resource management, flexibility and ambiguity, collecting data, and systematicity. In the knowledge building element, the learning skills shown by collaborative problem solvers involve many steps described in the cognitive and social aspects of collaborative problem-solving. Through their progress in collaborative problem-solving tasks, individuals can learn about the content domain, learn strategies, and how to deal with setbacks, or learn how to coordinate, collaborate, and negotiate with others. In other approaches to solving complex problems, the possibility of a hierarchy for cognitive development is related to problem-solving, which is an approach that can help us imagine categories of ordered responses to problem-solving challenges. This element has three skills, namely, relationships, contingencies, and hypothesis.

3.3.3 Keywords for Rubrics of CPS Assessment

Three questions were developed each for junior and senior high schools representing three levels of difficulty: easy, moderate, and complex. For each subsequent question, it is equipped with rubrics and relevant keywords. The rubrics are organized with regard to social and cognitive CPS domains. Each domain category is divided according to social and cognitive domains. Further, rubrics’ keyword on each domain dimension are grouped into beginner, emerging, intermediate, and advance adversity (Table 10). The preparation of keywords for each rubric developed is influenced by the indicators attached to each of the CPS questions (see Table 3). The keywords developed fall into generalization keywords and specialization keywords. Generalization keyword apply for every CPS question developed, whereas specialization keywords apply only to each of specific CPS question’ indicator.

Table 10. Generalization and specialization of keywords based on CPS questions given
CPS assessment can be done using several types of approaches. The primary key in developing a CPS assessment instrument is to consider the focus of measuring the collaborative skills to be assessed using keywords and scoring system. The focus of the measurement includes quality of the solution and the object assessed during the collaboration process, the log file analysis, the process of making the solution, the process within the team and the structure of the interaction, the quality, and type of collaborative communication. However, of all the measurements, the biggest challenge is to ensure that the approach in the assessment can capture a portrait of CPS skills and convert them quantitatively. Indonesia uses a standard national language that is formally used in education. However, Indonesia has around 700 local languages. Elements of regional languages still influence communication occurring more than 5 times. The conversation was not immediately replied. It takes a long time to answer conversations with partners. According to the concept of atomic structure:... concept of isotope ...: If ..., then ...: If this ..., then ...: Apparently, we are different ways but the results will be obtained the same; How/what if we equate our understanding; Your effort is good; Our idea can be accepted; Has it been resolved yet? Wow, your idea is brilliant!; Good, let's apply your degree degrees; Let's look for other sources of information; We look for other sources regarding electrical circuits; Based on the discussion in the book ...; What are the characteristics of elements; Isotopes are the same as the same atomic number (Z); Z = number of protons; So what is isotope included are elements \( {}^{8}\text{B} \), \( {}^{12}\text{B} \), \( {}^{19}\text{F} \), \( {}^{22}\text{F} \), \( {}^{40}\text{Ca} \), \( {}^{20}\text{Ca} \); Isobar: atoms that have the same mass number (A); The atomic number is different; So which includes isobars: \( {}^{8}\text{B} \), \( {}^{12}\text{B} \), \( {}^{19}\text{F} \), \( {}^{22}\text{F} \), \( {}^{40}\text{Ca} \), \( {}^{20}\text{Ca} \); Isobar: atoms that have the same mass number (A); But the atomic number (Z) is different; So which includes isobars: \( {}^{8}\text{B} \), \( {}^{12}\text{B} \), \( {}^{19}\text{F} \), \( {}^{22}\text{F} \), \( {}^{40}\text{Ca} \), \( {}^{20}\text{Ca} \); Isobar: atoms that have the same mass number (A); You/I am looking for atomic number values; I am looking for information in books only; Work respectively; I try; You try; Here's the answer; Based on references in the book ...; Communication occurs more than 5 times. The conversation was not immediately replied. It takes a long time to answer conversations with partners.
the daily conversation patterns of the students, also influenced by the everyday language in urban or rural areas where students live, as well as interactive chatting on social media. This condition reflects the complexity of compiling the keywords for each rubric of the CPS question given.

### 3.2.2 Keyword validation

The developed keywords are validated based on chat history that exported by the CPS system. The emersion probability of keyword is recorded in the CPS system, and it exported into excel form. It is recorded participant conversation and chats time history during the problem-solving processes. We conduct this qualitative analysis to validate the developed keywords (Table 11). Problem No.3 in the chemistry field is chosen as initial analysis processes, whereas the other problem number will be discussed in the further paper. Step of analysis divided into two parts; part 1 counting keywords that refer to the social domain and considering time chat interval to judge the participation aspect, part 2 counting keywords that refer to the cognitive domain.

| Participant | Keywords in chat history | Frequency of Concept Terms | Frequency of social terms | Time interval (min) | Analysis |
|-------------|--------------------------|----------------------------|--------------------------|---------------------|----------|
| 1           | What is Isotope          | 1                          | 0                        |                     | From this conversation, participants mention three concepts term. The terms are mention on the designed rubrics so that the keywords are valid can measure students CPS skill on the cognitive domain. In the social domain, time chat interval that consumes in this part less than 2 min, it showed that participants actively give respond to each other. Participant 2 contribute to partners’ understanding by explaining the meaning of atom. It is part of perception taking (social domain level 3, Table.3). |
| 2           | Isotopes are the same as the same atomic number | 2                          | 0                        | 0.59               |         |
| 1           | Which one is atom?       | 1                          | 0                        |                     | ‘atom’ is a fundamental concept that can solve the problem. It is put as one of the keywords in the rubric. Time chat interval data showed that participant responses to each other. They tried to build knowledge. Participant 2 contribute to partners’ understanding by explaining the meaning of atom. It is part of perception taking (social domain level 3, Table.3). |
| 2           | Atom is on the top of table as a, b, c | 1                          | 0                        | 0.36               |         |
| 1           | It means same as proton? | 1                          | 0                        |                     | “proton” put as one of a keyword in the designed rubric (cognitive domain). Participant 1 started to be able to connect the information obtained (knowledge building level 3), participant 2 contribute to partners’ understanding by giving information of formula (perception taking level 3, social domain). They participate actively in responding partner. |
| 2           | Yes, This is the formula: \(X\) | 1                          | 1                        | 0.57               |         |
| 2           | Number of atom, number of proton, number of electron | 3                          | 0                        |                     |         |
| 1           | Ok                       | 0                          | 1                        | 0.09               | Participant 2 add more information related to the concept to help partner understanding. They try to have the same understanding of the related tasks (social regulation level 3, social domain). Participant 1 give fast to respond to partner (participation level 3). |
| 1           | What is isobar?          | 1                          | 0                        | 0.23               | Participant 1, ask the definition of isobar to get |
Table 11 describes the analysis of chat history. It validates that 28 keywords of cognitive domain arose in communication processes among participants. However, in the designed rubric, the keywords number more than 28. It suggested that the validation process of the rubric should be conducted continuously. There are several words, which are not included in the rubrics. Therefore, it needs the enrichment of keywords in the rubrics. On the other hand, to measure social domain, we need to synthesize the conversation meaning or context. It needs more improvement in adding and classifying similar keywords.

This method of rubrics validation helps the developmental step so that the instrument can measure accurately. Communication is the focal center of assessing the participant’s CPS skills. It is a primary focus on constructing a shared understanding (Rosen and Foltz, 2014), besides quality solution and object generated during collaboration works, and those are the key challenge in

| Participant | Keywords in chat history | Frequency of Concept Terms | Frequency of social terms | Time interval (min) | Analysis |
|-------------|--------------------------|----------------------------|--------------------------|--------------------|----------|
| 2           | Isobar has same mass number | 2                          |                          |                    |          |
| 2           | Mass number equal to number of proton with neutron | 3                          |                          |                    |          |
| 2           | Let's find the isotope first | 1                          | 1                        | 0.54               | Participant 2 giving strategy to solve the problem. He is able to adapt problem-solving strategies based on information/references obtained (task regulation level 3, cognitive domain). |
| 1           | So the isotope is B, E, G | 2                          |                          |                    | Participant 1 respond rapidly by finding the answers (Participate level 3, social domain). |
| 2           | Yes, you’re right! | 1                          |                          | 3.56               | The chat showed that participant 2 make comments or share information with partners about their performance (social regulation, level 3, social domain). |
| 2           | Let's fill it in | 1                          | 1                        | 0.05               | ‘isobar’ is mentioned by participant 1 as concept term; however the sentence context refers to the social domain (social regulation level 3), that showed participant and partners try to have the same understanding on the related tasks. |
| 1           | Now, Let’s find the isobar Ok |                          |                          |                    |          |
| 2           | What is Isobar | 1                          |                          |                    | Participant 1, ask the definition of isobar to get more information. He is sensitive about the importance of getting more information (task regulation level 3, social domain). |
| 2           | Isobar have the same number of Mass | 2                          |                          |                    |          |
| 2           | Number of Atom, Amount of proton, Amount of Electron | 3                          |                          | 3.53               | Participant 2 respond rapidly by giving more information (participation level 3, social regulation level 3). ‘Isobar’, ‘mass number’ keywords are put in the designed rubric so that the keyword is valid. |
| 2           | eh neutron | 1                          | 1                        | 0.10               | Participant 1 giving answers based on the information from partners. Participant started to be able to connect the information obtained so that they can conclude a causal relationship and conceptual patterns based on the information obtained (knowledge building level 3, cognitive domain). |
| 1           | Then the answer is b c |                          |                          |                    |          |
| 2           | Right |                          |                          |                    |          |

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assessing CPS. Along the assessment process, challenges appear in assuming communication. It should be minimized by synthesizing information from individuals. Choosing keyword similarity is one of solution that was taken in analyzing chat history data in this research. Another approach has been to analyze the streams of open-ended communication in collaborative situations. For example, Foltz and Martin have used semantic and syntactic analyses of team communications in order to score individual, and team performance as well as classifies individual statements to different collaborative skills and Erkens and Jansen have used techniques to code collaboration protocols. Therefore, analysis of the content and structure of communication streams can provide measures of grounding and precision of references among team members, mutual goal establishment, progress toward goals, negotiation, consensus, leadership, and quality of solutions generated (Rosen and Foltz, 2014)

4. CONCLUSION

Collaborative problem-solving skills integrates two main domains: social and cognitive. Assessing students’ CPS skills should consider these domains. Aspects of the social domain consist of participation, perspective-taking, and social regulation. Cognitive domain aspect consists of task regulation and knowledge building. CPS questions are built refer to content competencies in curriculum national 2013, need higher-order thinking skills to solved and integrate multidiscipline context using the STEM approach. It consists of contextual problematic in daily life to apply and elaborate multidiscipline concept. The analytic rubric is developed to measure CPS accurately; however, the keywords to assess the indicator’s aspects in rubric should define precisely. For further research, the sample of the participant will be larger and coverage many regions in Indonesia to enrich keywords so that the instrument could be used nationally.

ACKNOWLEDGEMENT

This work would not have been possible without the financial support of the Center for Educational Assessment (Pusat Penilaian Pendidikan) Agency of Research and Development Ministry of Education and Culture of the Republic of Indonesia. The researchers are mainly indebted all involved schools, teachers, and students who have been very supportive and cooperative in the completion of this research.

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