Development of Mathematics Collaborative Problem-Solving Skills Scale

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Abstract. Collaborative Problem Solving (CPS) is one of the most critical and necessary skills in education and workplace; hence, its assessment is a necessary subject of research. CPS assessment tools must be crafted to establish the effectiveness of the pedagogies to CPS development. Therefore, to address these gaps, this study developed a Likert scale called Mathematics Collaborative Problem Solving Skills (MaCoPSS) Scale. The scale development followed the process: (1) item generation, (2) item evaluation, (3) try-outs, (4) Exploratory Analysis, (5) final evaluation. Open-ended questionnaires were administered to 273 respondents. After analysis, 551 statements were produced as initial item pool. The items are evaluated and only 59 of them are used for the draft scale for the try-outs. The scale was administered to 648 students for the try-outs and responses were cleaned then subjected to Exploratory Factor Analysis (EFA). Two factors, namely social skills (SS) and problem-solving skills (PSS) were extracted. To establish internal consistency, the factors are correlated to one another (r=0.708), and factor to total raw score (TRS) correlations are highly correlated: SS-TRS (r=0.955) and PSS-TRS (r=0.894). The final scale consists of 27 SS and 17 PSS items. The overall reliability coefficient of the scale is α=0.941. The resulting scale is considered valid and reliable.

1. Introduction
Lev Vygotsky in his Mind in Society, notes that social interaction is essential to learning and that learning implies development [24]. It is in this sociocultural perspective of learning that collaborative learning is seen as an effective means of facilitating learning even in the context of developing problem-solving skills. The idea of collaboratively solving problems is not new in literature [17]. However, it is only recently that collaborative problem solving is extensively studied in terms of teaching, learning and assessing.

Collaborative problem-solving (CPS), as a construct, brings together individual problem-solving and the collaborative social process of learners working together [17]. In the 21st century, CPS is one of the most critical and necessary skills both in education and the workplace [12]. Project Based Learning (PBL) approach to Science Technology Engineering and Mathematics (STEM) education [1]; National Council of Teachers of English [26] recognizes the importance of CPS. Furthermore, it is included as one of the dimensions in work readiness assessment [20]. These only show the importance of understanding the dynamics of CPS. Hence, many researchers find it necessary to find a framework of developing and assessing the said skill [10, 11, 12, 13, 19, 20, 25].
With several frameworks for CPS emerging from different studies, methods of assessing CPS is not far from being realized. For example, Organization for Economic Cooperation and Development’s (OECD) Programme for International Student Assessment (PISA) and Assessing and Teaching 21st Century Skills (ATC21S) projects conceptualized frameworks for assessing CPS in large assessment contexts. PISA first introduced CPS as one of the innovative domains to assess during the 2015 PISA. PISA assessment items are referred to as CPS units where the students solve a series of problems. The students will select predetermined responses in the “chat space” provided [12]. On the other hand, while the ATC21S project used a similar system, the main difference lies in the Human-Human interaction between students. Notice that both assessment systems have cognitive skills and social skills dimensions but inevitably utilize an online platform for assessing. With the emergence of such assessment systems integrating Information and Communication Technologies (ICT), the availability of easily accessed methods of assessment is meager. It is in this context that the problem arises.

In the Philippines, Teaching Mathematics through Problem Solving (TMPS) as an innovative approach utilizing collaborative problem solving [2, 5] is being promoted by the University of the Philippines' National Institute for Science and Mathematics Education Development (UP-NISMED) since 2006 [15] and the Department of Science and Technology, Science Education Institute's (DOST-SEI) Project Science Teachers Academy for the Regions (STAR) since 2014 [6]. The approach's effects on student achievement have been fairly documented in the literature. However, the approach's effects on the development of CPS skills is not yet established.

Therefore, to establish the effect of an approach to the development of CPS skills means that a tool for measuring the level of CPS skills must be devised. With the limitations of the existing CPS assessment systems, this study addresses the gap of CPS assessment in the classroom setting by providing an alternative method of measuring CPS skills through developing a Mathematics Collaborative Problem Solving Skills (MaCoPSS) Scale. To develop a scale for collaborative problem solving as a tool for measuring collaborative problem-solving skills of the students. Specifically, to attain this general objective, this study aims to (1) Describe the process of the development of the MaCoPSS Scale; (2) Determine the dimensions of collaborative problem solving; (3) Determine the construct validity of the Mathematics Collaborative Problem Solving Skills (MaCoPSS) Scale; (4) Establish the reliability of the Mathematics Collaborative Problem Solving Skills (MaCoPSS) Scale.

2. Theoretical Background
The theoretical consideration for the scale development of the mathematics collaborative problem-solving instrument is primarily anchored upon the Collaborative Problem Solving framework of [13]. The same framework was used by the ATC21S project of the University of Melbourne undersigned by CISCO, Intel®, and Microsoft®. The framework is selected as it illustrates some essential skill of the highest cognitive domain for Mathematics [16]. Furthermore, the framework provides analytic criteria for the specified skill as it utilizes a developmental approach to learning and assessment [10].

The framework is composed of two domains: cognitive and social domains. Each domain has specified skills and behavioral indicators (See Table 1). Such dimensions are also seen across different known frameworks. The ATC21S assesses collaborative problem solving in a manner that social skills and cognitive skills are assessed parallel-wise, meaning social skills are measured differently from the cognitive skills [25]. The advantage of this framework is that it provides a clear picture of what to improve concerning CPS skills.
Table 1. Collaborative Problem Solving Skills and Indicator Design

| Element                      | Behavioral Indicators Based on                                      |
|------------------------------|---------------------------------------------------------------------|
| Social skills                |                                                                      |
| Participation                |                                                                      |
| Action                       | Activity within environment                                         |
| Interaction                  | Interacting with, prompting, and responding to contributions of others|
| Task completion/perseverance | Undertaking and completing a task or part of a task individually    |
| Perspective taking           |                                                                      |
| Adaptive responsiveness      | Ignoring, accepting, or adapting contributions of others            |
| Audience awareness           | Awareness of how to adapt behavior to increase suitability for others |
| Social Regulation            |                                                                      |
| Negotiation                  | Achieving a resolution or reaching compromise                       |
| Self-evaluation              | Recognizing own strengths and weaknesses                            |
| Transactive memory           | Recognizing the strengths and weaknesses of others                  |
| Responsibility initiative    | Assuming responsibility for ensuring parts of the task are completed by the group |
| Cognitive Skills             |                                                                      |
| Task regulation              |                                                                      |
| Organizes                    | Analyzing and describing a problem in familiar language             |
| Sets goals                   | Setting a clear goal for the task                                  |
| Resource management          | Managing resources or people to complete a task                     |
| Flexibility and ambiguity    | Accepting ambiguous situations                                      |
| Collects information         | Exploring and understanding elements of the task                    |
| Systematicity                | Trying possible solutions to a problem and monitoring progress      |
| Learning and knowledge building |                                                               |
| Relationships                | Identifying connections and patterns between and among elements of knowledge |
| Contingencies/rules          | Using understanding of cause and effect to develop a plan           |
| Hypothesis                   | Adapting reasoning or course of action as information or circumstances change |

Source: [11, 13]

3. Methods
This study employs the sequential exploratory mixed methods design [4]. The study started with gathering of qualitative data from an open ended questionnaire answered by junior high school students and pre-service teachers. The data were analyzed to be the input for drafting the scale. Quantitative data were then gathered from the drafted scale. Psychometric analysis methods were employed to extract latent factors, establish validity and reliability.

3.1. Research Subjects
The open-ended questionnaires were administered to 237 students and pre-service teachers. The developed Mathematics Collaborative Problem Solving Skill (MaCoPSS) Scale was tried-out to 648 Grade 8 to Grade 10 junior high school students in Iligan City for the S.Y. 2018-2019. The respondents were from six (6) schools from the ten (10) randomly selected public high school. The selected classes will have to pass the basic criterion of having the students undergone collaborative activities during the current grading period during the scale administration.
3.2. Data Collection

The data gathering procedure was divided into the development phase and the try-outs phase; which is also the validation phase. The development phase was also divided into sub-phases: item generation phase, drafting phase and item evaluation phases. Try-outs phase was divided into two sub-phases: massive try-outs phase, factor analysis phase, and the final evaluation phase. After the series of tests, the developed scale was revised accordingly. Then, the panel of specialists evaluated the final scale.

In the Development Phase, Item Generation started with the administration of the open-ended questionnaires based on the CPS framework. The resulting pool of items was thematically analyzed by identifying keywords. Such keywords form the basis for the derived statements. The statements are then categorized to the framework of the study. Statements ‘fitting’ the framework were then be subjected to evaluation and were revised. The outcome of this phase is the “drafted MaCoPSS Scale.”

For the large-scale try-outs of the drafted MaCoPSS Scale, all 26 public high schools in the division of Iligan City were considered. Random sampling was used to select ten (10) public high schools. Out of the ten (10) selected schools, only six (6) schools responded favorably. Factors like proximity limited the administration of the scale to these six (6) schools until the quota of 590 was achieved. This quota is based on [3] noting a commonly acceptable ratio of 1:10 for exploratory studies in factor analysis. This ratio indicates that there should be at least ten (10) observations per generated item. After the massive try-outs, the factor analyses were conducted.

Validity and reliability tests were also computed. At this point, a set of identified evaluators evaluated the MaCoPSS Scale. After their evaluation, the resulting outcome was termed the "validated MaCoPSS Scale.”

3.3. Research Instrument

3.3.1. Open Ended Questionnaire. This questionnaire is a researcher made open-ended questionnaire, based on the collaborative problem-solving framework adapted for this study, administered to generate the statements for the scale development. The questions are as follows: (1) 1. How do you solve a math problem? (2) How do you solve a mathematics problem if you are working in a group?

3.3.2. Item Statement validation guide. This guide is taken from the guidelines on scale development by [7]. This guide was used in the evaluation of the generated statements before try-outs.

3.3.3. Scale Evaluation Rubric. This rubric is an adopted rubric from an unpublished graduate thesis and guidelines of [7], which was used by the panel of evaluators to evaluate the developed Mathematics Collaborative Problem Solving Skill (MaCoPSS) Scale.
4. Results and Discussion
This chapter presents the discussion on the development of the MaCoPSS Scale, from the item generation down to the exploration of its dimensions.

4.1. Development Phase

4.1.1. Item generation. The validated open-ended questionnaire was then administered to select junior high school students in a purposively selected high school and to select pre-service teachers. A total of 239 respondents were asked to answer the open-ended questionnaires, and two of the respondents were not permitted by their parents to take part in the study. Hence, only 237 responses were recorded, encoded and analyzed.

The respondents of the open-ended questionnaires are mostly comprised by junior high school students as they are the intended subjects by which the scale is made for: Grades 7 (n=43) and Grade 9 (n=56) are students under the instruction of one teacher whose pedagogy includes ‘group activity’ strategies both on lesson modelling and assessment. While Grades 8 (n=57) and Grade 10 (n=58) are under the instruction of another teacher whose pedagogy mostly composes of the utilization of the 5E model of learning and Teaching Mathematics through problem-solving, both of which utilizing collaborative strategies. While junior high school students comprise most of the respondents, taking the pre-service perspective is also important. Pre-service teachers have been asked to answer the open-ended questionnaires to provide a perspective of an instructor, as they are trained to facilitate different teaching pedagogies that employ both collaborative and individual teaching methods. This set of pre-service teachers are selected on the basis that they have been sufficiently exposed to a strategy, teaching mathematics through problem-solving, which collaborative problem solving is at its core [2, 5]. As teachers on training, they provided an additional perspective not observed by the junior high students.

The first question in the open-ended question: “How do you solve a math problem?” was intended to explore students’ behavior, strategies and skills in solving problems individually, while the question “How do you solve a mathematics problem if you are working in a group?” was intended to explore students’ behavior, strategies and skills when solving problems in a group. The first question is necessary as it provides a baseline as to how students individually manage tasks. This is also one dimension of CPS, while the second question primarily focuses on the social aspect of problem solving. The figure below shows the process of item generation forms the open-ended questionnaire responses to the derivation of the declarative statements for the drafted MaCoPSS Scale.

![Image](https://via.placeholder.com/150)

**Figure 2. Items Generation Flowchart**

The raw responses were encoded and translated to English, for the analysis. The thematic analysis utilizes the strategy of word frequency count. Frequently occurring words describe the concepts the students answer in the open-ended questions. Similar words are counted as one, e.g., solving has 450 occurrences which also counts solve, solved and solving. Each of the words counted as ‘frequently occurring’ is all reviewed and evaluated. The evaluation is focused on whether a word
signifies a course of action, that is, an action word; and a word that would signify a concept relevant to CPS. From the generated pool of considered keywords, declarative statements are then derived from them. Each declarative statement has at least one keyword from which it is derived. A sample is shown below how a declarative sentence is derived.

| Raw Response: |
| S3: [1] I always try my best not to be seen as useless and unhelpful. [2] And so I end up trying to solve all of the problems by myself first and then ask questions if there are some things that I don't quite understand or needs to be clarified. [3] I don't usually share what I know unless they ask me because I don't want to be seen as a "know-it-all." [4] However, I do like it when I am able to solve a problem, and then they ask me questions regarding it, I feel like I'm being helpful for the first time. C33 |
| Keyword: ASK |
| Breakdown of sentence [2] |
| • I end up trying to solve all of the problems by myself first. S3, 2a, C33 |
| • I ask questions if there are some things that I don't quite understand or needs to be clarified. S3, 2b, C33 |
| Statements derived [2b] |
| I ask questions if there are things that I don't understand. C33 |
| I ask questions if there are things that need clarification. C33 |

Figure 3. Sample derivation of statements

Statement three (S3) is a sample raw response of the respondent C33 for Q2. The keyword under consideration is ‘ask,’ and the sentence by which it appears is sentence 2. Sentence 2 is then divided into two declarative statements. Considering the keyword ‘ask,’ then, only from S3-2b will the declarative statement be derived. The researcher then simplified this raw response to its simplest form possible without losing the sense of meaning from the raw response. Then, two final statements are derived from keyword ‘ask’. Reiterating the process of deriving declarative statements from the raw responses with the observed keywords, several declarative statements are derived from each keyword. This process resulted in producing 551 declarative statements. These statements were cross referred to the adapted framework by [13] and identified 119 statements that is closely related to the behavioral indicator defined by the framework.

4.1.2. Drafting of MaCoPSS Scale. A framework of Collaborative Problem Solving (CPS) was adopted in this study after a review of literature. This framework is from the work of [13] for the ATC21 Project. The framework identifies skills and indicators of the two major dimensions of CPS: Social Skills and Cognitive skills. The derived declarative statements are screened using this framework.

These statements were subjected to a simultaneous item evaluation and content validation conducted through a group discussion of teachers to maximize the efficiency of the evaluation process. The evaluation is guided by the validation guide adapted from a chapter in the book of [7] on scale development. It comprises of characteristics encompassing (1) item clarity and (2) presence of negatively stated and positively stated items. The evaluators selected have at least ten (10) years of experience in the field as a math teacher and are implementors of collaborative strategies of teaching mathematics. Table 2 shows some sample statements evaluated.

With the researcher facilitating the item evaluation, the teacher evaluators evaluated the items and content validated them based on their actual classroom experience. Out of the 119 drafted statements, 60 statements were rejected with the following reasons: statement length, clarity, and inapplicability. Notice sample items No.1 and No.4 in Table 2. Sample statement 1 is observed to have contained two concepts and was broken down into two separate statements. Whereas, sample
statement 4 was rejected due to clarity of statement. After the evaluation and content validation of the statements, the drafted MaCoPSS Scale was produced having 59 statements.

| No. | Statement                                                                 | Q No. | Accept | Reject | Remarks                      |
|-----|----------------------------------------------------------------------------|-------|--------|--------|------------------------------|
| 1.  | I will allow my group mates to correct me, I will not assert that my answer is correct (67) | 2     | X      |        | Double Barrel: Break down into two. |
| 4.  | I analyze the clue words that can help me solve the problem. (7)           | 1     |        | X      | Analyze: too broad and is not very clear. |

4.2. Try-outs Phase

4.2.1. Administration of Drafted Scale. The respondents were distributed across the grade levels 8-10 for the try-outs phase of the scale development. Of each of the school randomly selected, three classes were selected one from each grade level from grade 8 – 10. Due to schedule conflicts, some classes which were selected for the try-outs were not able to answer the try-outs survey. Although there was a total of 235 Grade 8 students from 5 schools, 211 Grade 9 students from 5 schools and 202 Grade 10 students still, from 5 schools, only 565 of the responses were considered valid.

4.2.2. Exploratory Factor Analysis. An exploration of the collected data was conducted, and several low extremes and outliers were identified and removed to prevent misleading interpretation of the results. These outliers were based on the average means of each of the respondents’ answers. The kurtosis (-0.279) and skewness (-0.131) values of the means revealed that the data collected is relatively not normally distributed. Considering the normality of the data set, [3] noting that there is an advantage when using Principal Axis Factoring in a relatively non-normal data. Hence, the extraction method used is principal axis factoring or PAF.

4.2.3. Factors Extracted. Before the conduct of the factor analysis, Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) and Bartlett’s Test of Sphericity was tested with the given data [8]. Results showed that the data sample is adequate with KMO value of 0.925. The KMO-MSA measures whether the data is suited for factor analysis. [14] noted that values 0.9-1.00 as ‘marvelous,’ meaning that the data is well suited for factor analysis. Bartlett’s Test of Sphericity tests the hypothesis that the correlation matrix is an identity matrix. Thus, if it is an identity matrix, there is no relationship between variables. This correlation matrix must not be an identity matrix to proceed to factor analysis. The results (sig. p=0.000<0.05) indicated that the correlation matrix for the data is not an identity matrix as there are significant relationships between variables. Therefore, the given data is suitable for factor analysis.
There are two major dimensions of CPS considered in this study, that is, social and cognitive. But to verify and ascertain the number of factors to be retained, a parallel analysis was conducted (Figure 4). The parallel analysis makes use of the actual eigenvalues and a randomly generated eigenvalues given the number of variables and the sample size. The scree plot of the actual and the randomly generated Eigenvalues intersects at factor 4. With the actual Eigenvalue of factor 4 lesser than the randomly generated eigenvalue, suggests that the scree plot "flattens" from factor 4, indicating further that only the three (3) factors are to be retained as suggested by [21, 22, 23].

4.2.4. Explored Dimensions of MaCoPSS Scale. Table 3 shows the rotated factor loadings of the conducted exploratory factor analysis. As a rule of thumb, only variables with a minimum factor loading of 0.32 are interpreted [3]. Factor loading of <0.32 that the variable does not correlate well with the factor extracted. Therefore, based on the factor loadings, 9 statements or variables were discarded. Table 6 shows the factor loadings from the EFA.

Most of the items loaded to factor 1 categorized as Social Skills (SS) in the framework of [13]. Essentially, this factor is the social skill factor. The social skill factor contains statements indicating skills in areas of participation, perspective taking, and social regulation. This confirms the existence of a social dimension in the CPS construct.

Statements loading under factor 2 are categorized as Problem Solving Skills (PSS). The statements loading on factor 2 indicates skills in task regulation and learning and knowledge building. This coincides with the CPS construct of bringing together social dimension and cognitive dimensions of learning.

Finally, factor 3 is categorized as Individualistic Tendencies (IndT). While these items load significantly on a factor, they do not necessarily contribute to successful collaboration. [18] suggested that one of the mechanisms that contribute to poor performance in groups is called social loafing where members of the group do not engage believing that someone else will accomplish the task at hand. Items such as “I usually find it better to work alone” or “If I perceive that my group mates want to work alone, I will leave them be” indicates such cases. Reliability tests also indicates that this factor is not reliable. Hence, this factor was not considered.

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**Figure 4. Parallel analysis scree plot**
Table 3. Factor Loadings Pattern Matrix of the MaCoPSS Scale

| Pattern Matrix | Factor 1 | Factor 2 | Factor 3 | Factor 1 | Factor 2 | Factor 3 |
|----------------|----------|----------|----------|----------|----------|----------|
| ITEM037        | .668     | -.102    | .035     | ITEM019  | .270     | .249     | .012     |
| ITEM048        | .665     | -.068    | -.139    | ITEM026  | .262     | .247     | -.255    |
| ITEM049        | .635     | -.042    | .017     | ITEM008  | -.047    | .633     | -.070    |
| ITEM032        | .610     | -.154    | .091     | ITEM015  | -.018    | .563     | -.031    |
| ITEM039        | .602     | -.141    | .019     | ITEM005  | -.098    | .554     | -.045    |
| ITEM029        | .560     | -.093    | .074     | ITEM009  | -.001    | .550     | -.122    |
| ITEM054        | .541     | .050     | -.004    | ITEM012  | .009     | .529     | .079     |
| ITEM050        | .533     | .072     | -.058    | ITEM018  | .054     | .511     | .043     |
| ITEM058        | .514     | .115     | -.010    | ITEM007  | -.103    | .509     | .193     |
| ITEM040        | .496     | .013     | -.102    | ITEM024  | -.063    | .479     | .311     |
| ITEM036        | .478     | .157     | .032     | ITEM025  | -.108    | .467     | .195     |
| ITEM047        | .477     | .154     | -.134    | ITEM022  | .040     | .446     | .062     |
| ITEM059        | .475     | .100     | -.196    | ITEM023  | .056     | .445     | -.023    |
| ITEM052        | .474     | .049     | -.003    | ITEM006  | .064     | .445     | .038     |
| ITEM044        | .473     | .095     | -.056    | ITEM003  | .006     | .437     | -.110    |
| ITEM030        | .472     | .138     | .044     | ITEM004  | .055     | .431     | -.024    |
| ITEM035        | .471     | -.088    | .300     | ITEM021  | .189     | .409     | -.094    |
| ITEM046        | .458     | .042     | -.022    | ITEM017  | .213     | .382     | .027     |
| ITEM011        | .458     | .074     | -.025    | ITEM002  | .131     | .361     | -.175    |
| ITEM057        | .449     | .066     | .020     | ITEM016  | .235     | .308     | -.010    |
| ITEM053        | .445     | -.099    | .170     | ITEM013  | .071     | .293     | .175     |
| ITEM045        | .441     | .151     | .007     | ITEM001  | .100     | .227     | .103     |
| ITEM055        | .412     | .163     | -.001    | ITEM014  | .169     | .172     | .092     |
| ITEM056        | .407     | .091     | .088     | ITEM010  | .147     | .162     | .084     |
| ITEM033        | .402     | .247     | -.011    | ITEM028  | -.020    | .128     | .489     |
| ITEM031        | .401     | .192     | .031     | ITEM020  | -.135    | .266     | .466     |
| ITEM034        | .367     | .052     | .148     | ITEM043  | .125     | -.064    | .462     |
| ITEM027        | .349     | .024     | .219     | ITEM051  | .003     | -.023    | .364     |
| ITEM041        | .310     | -.051    | .181     | ITEM038  | .127     | .197     | .330     |
| ITEM042        | .287     | .215     | -.003    |

Note: Extraction Method: Principal Axis Factoring. Rotation Method: Promax with Kaiser Normalization. Rotation converged in 6 iterations.
4.2.5. Establishing Construct Validity. The construct validity is established by determining the correlation of the retained extracted factors, SS and PSS. Total raw scores (TRS) for the retained factors are also correlated to the scale TRS. This is to establish that each of the factors contributes significantly to the total raw score. Lastly, a panel of evaluators evaluated the scale developed from the retained items.

Table 4. Correlations of Factors

| Factor-Factor                                      | Correlation |
|---------------------------------------------------|-------------|
| Social Skills – Problem Solving Skills            | 0.708       |
| Social Skills – Individualistic Tendencies        | -0.068      |
| Problem Solving Skills – Individualistic Tendencies | 0.028       |

A correlation value of $r=0.781$ indicates that there is a high correlation between factors SS and PSS, while IndT does not significantly correlated to any of the other factors. The removal of the third factor is also supported by literature [18]. Hence, only SS and PSS factors are retained to achieve a constructively valid instrument.

Table 5. Correlations of Factor Scores and Total Raw Scores

| Factor-TRS                                      | Correlation |
|-------------------------------------------------|-------------|
| Social Skills Scores – TRS                       | 0.955**     |
| Problem Solving Skills – TRS                     | 0.864**     |

**Correlation is significant at the 0.01 level (2-tailed)

A correlation value of $r=0.955$ and $r=0.864$ for SS-TRS and PSS-TRS, respectively, means that This means that both the social skills factor and the problem-solving skills factor scores significantly contribute to the total raw scores. With both coefficients being significant at 0.01 level of confidence, we conclude that the scores obtained in the identified dimensions of the scale for collaborative problem-solving skills have a significant contribution to the total raw score.

4.2.6. Final Evaluation. Using a modified rubric, each dimension can be rated with the highest rating of twenty (20) and the lowest of four (4). Two Mathematics Education evaluators and a Registered Psychometrician and Guidance Counselor evaluated the scale. The social skills dimension was rated with an average of 16.5, interpreted as ‘Very Good’ scale while the Problem-Solving Skills Dimension was rated with an average of 18.33, interpreted as ‘Excellent’ scale. Overall, the whole scale is evaluated with the average rating of 17.42 out of 20, interpreted as ‘Excellent’. One item was removed from the SS as it was redundant with another item.

4.2.7. Establishing Reliability. The reliability of the scale and its explored factors are established by computing Cronbach’s alpha. These tests would indicate the reliability and internal consistency of the scale. An acceptable rule of thumb for reliability is that it must have a Cronbach alpha value of not lesser than $\alpha=0.70$ [9]. The developed scale has a total reliability value of $\alpha=0.931$ with the third factor removed. The problem-solving skills factor has a reliability of $\alpha=0.846$ while the social skills have reliability of $\alpha=0.912$. These indicate that the scale is highly reliable with the given sample (See Table 8).

The final validated instrument contains 44 items 27 of which are under social skills and 17 items under the problem-solving skills (See Appendix). After establishing the construct validity and the reliability of the scale, the scale can be used to measure collaborative problem-solving skills in two dimensions, namely, social skills and problem-solving skills. The items under social skills dimension
measures skills based on indicators of participation, perspective taking and social regulation skills. Participation indicators have seven (7) items, Perspective taking have four (4) items, and Social regulation has 16 items. The items under problem-solving skills dimension measure the skills based on indicators of task regulation and Learning and Knowledge building. Task regulation has 13 items, and learning and knowledge building has four (4) items. The two dimensions identified highly correlate to one another, and each of the dimensions' scores significantly contributes to the total raw score of the scale.

Table 6. Reliability Coefficient of the Developed Mathematics Collaborative Problem Solving Skills Scale

| Collaborative Problem Solving Dimensions in Mathematics | No. of Items | Cronbach’s α |
|--------------------------------------------------------|--------------|--------------|
| Problem Solving Skills                                 | 17           | 0.846        |
| Social Skills                                          | 27           | 0.920        |
| Developed MaCoPSS Scale                                | 44           | 0.941        |

5. Conclusion and Recommendation

Collaborative problem-solving skills have two dimensions namely, the social skills and problems solving skills. Social skills include participation skills, perspective taking skills and social regulation skills, while Problem Solving skills include task regulation and learning and knowledge building [13]. The scale developed is theoretically sound, valid and reliable as the tests indicate. While the developed scale is found to be theoretically sound, valid and reliable, this is only true for the given sample. Furthermore, the scale format may affect the responses of the respondents. Hence, the following are recommended: (1) The scale can be administered to another group of respondents to strengthen the construct validity of the scale. (2) Additional scale items may be considered as one of the mathematics education specialists suggested. (3) A 5-choice format may be adapted to verify whether the number of scale choices affects the student responses.

Since the developed scale was found to be theoretically valid and reliable, hence the following are also recommended: (1) The scale shall be used in actual classroom setting to verify its applicability and usability (2) A factor indicating individualistic tendencies indicates that there is a need to develop CPS through relevant pedagogies in the classroom, especially in the mathematics classroom.

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APPENDIX A

VALIDATED MATHEMATICAL COLLABORATIVE PROBLEM-SOLVING SKILLS (MACOPSS) SCALE

Mathematics Collaborative Problem-Solving Skills (MaCoPSS) Scale

Last Name: (Optional)__________ First Name: ______________ MI: _____ Grade Level*:____
School*:__________________ Gender*: [  ] Male [  ] Female

*Please provide necessary information

Instructions: Read each statement carefully. Place an X mark on the choice corresponding the degree of your agreement to the statement. Answer all items with honesty. There are four choices for each statement which corresponds to the following:

1 – Strongly Disagree  2 – Disagree   3 – Agree   4 – Strongly Agree

The example below indicates that you AGREE with the statement: ‘I ask my teacher if I don't understand.’

| Statement | 1 | 2 | 3 | 4 |
|-----------|---|---|---|---|
| 1. I ask my teacher if I don’t understand. | | | X | |

| STATEMENT | 1 | 2 | 3 | 4 |
|-----------|---|---|---|---|
| 1. I repeatedly read the problem if it is difficult. | | | | |
| 2. I take note of important details in the problem. | | | | |
| 3. I mark the important data or words to guide me in my solving. | | | | |
| 4. I make sure that I know the meaning of the words in the problem. | | | | |
| 5. I try to illustrate the problem so that I could understand it better. | | | | |
| 6. I use variables to represent quantities. | | | | |
| 7. I always make sure that I have the goal in mind when solving. | | | | |
| 8. After understanding the problem, I will identify what is unknown to solve the problem. | | | | |
| 9. If I can’t find a suitable answer, I seek help from knowledgeable people on how to solve it. | | | | |
| 10. After finding an answer using one method, I use another method to confirm my answer. | | | | |
| 11. I will identify the given quantities first. | | | | |
| 12. I try to figure out if the problem is already discussed in class or not. | | | | |
| 13. After obtaining necessary information from the problem, I determine what series of operations should I use. | | | | |
| 14. I solve step-by-step so that I can look back and know what I am doing. | | | | |
| 15. I look for patterns in the problem for me to solve it. | | | | |
| 16. I recall of my past lessons that I can apply on the given problem. | | | | |
| 17. I associate the given problem to the real world to come up with practical ways to solve the problem. | | | | |
| 18. I manipulate the formula after determining what variables are missing. | | | | |
### Social Skills

|   |   |
|---|---|
| 19. | I can communicate well my solution to my classmates. |
| 20. | I ask my group mates how do they understand the problem. |
| 21. | If somebody explains his answer to the group, I listen to him or her and react if necessary. |
| 22. | We talk as a group on all possible solutions that will help us come up with an answer. |
| 23. | I compare my answers to my group mates’ after solving the problem on my own. |
| 24. | I read and analyze the problem myself before sharing anything to my group mates. |
| 25. | I must consider the ideas of my group mates whether their ideas are applicable or not. |
| 26. | While listening to my group mates’ understanding of the problem, I also compare it to my understanding and determine which is more reasonable. |
| 27. | If we arrive at different answers, then I will ask my group mates why their answers are like that. |
| 28. | If I don’t have ideas on my own, I will listen to the ideas of my group mates. |
| 29. | I will allow my group mates to correct me. |
| 30. | When working as a team, the team members must have a common goal. |
| 31. | We agree which method to use by comparing and contrasting ideas given by the group. |
| 32. | Everyone in the group must agree with the final solution. |
| 33. | We make sure that all of us understand the process of solving the problem. |
| 34. | When I can’t solve the problem on my own, I ask my group mates how to solve the problem. |
| 35. | I share my thoughts if I think my solution is correct. |
| 36. | If I know the answer, I would help my group mates so that they would get the correct answer. |
| 37. | If my answer differs from my group mates, I will try to find my mistake. |
| 38. | Even if my answer is not correct, at least I am able to give an idea that might guide us to solve the problem. |
| 39. | I pay attention if others will not understand the problem to assist them. |
| 40. | I first ask my group mates if they can properly comprehend the situation, if there are questions, then clarify. |
| 41. | I would assign problems/tasks for each one, so no one will be doing nothing. |
| 42. | I try to keep everyone moving, not relying on one person. |
| 43. | I try to get everyone’s attention before asking questions how they would solve the problem. |
| 44. | I engage my group mates to share their ideas on how they solve the problem to make better solution for the problem. |