How to Measure Complex Problem Solving Skills: A Systematic Literature Review

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Abstract. The purpose of this study is to conduct a literature review on measuring the Complex Problem Solving (CPS) skills. This study examines the instruments used to measure the CPS skills in the past 10-15 years. In addition, this study also describes indicators for measuring CPS skills. This type of research used in this study is a systematic literature review study using the PRISMA principle. The results showed that most of the CPS measurement instruments used in the journal articles reviewed were computer-based tests. Computer-based tests were chosen because they can simulate a dynamic environment. The CPS studies reviewed did not use certain CPS indicators and became a standard. The CPS indicators used are adjusted to the research theme being carried out.

Key word: complex problem solving; mesurements; prisma statement.

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INTRODUCTION

The world has just entered the era of the industrial revolution 4.0 where humanity is facilitated by an internet connected network system. Distance and time are no longer the problem of someone to interact. The industrial revolution 4.0 was first introduced by a group of German business people in 2011. They sought to improve industrial competitiveness through the integration of cyber physical systems into production systems (Kagermann, Luke, & Wahlster, 2011).

One feature of the industrial revolution 4.0 is higher ambiguity (Leinweber, 2013; Heckleu, Galeitzke, Flachs, & Kohl, 2016; Fitsilis, Tsoutsa, & Gerogiannis, 2018). As a result, humans face complex problems in the 21st century. The World Economic Forum (2020) explained that the top ten skills most needed by 2025 is complex problem solving skills (CPS).

In the present and future, CPS skills have a role in one's success in the work environment, community environment and family environment. CPS is also needed by an individual to be able to actively participate in social life in the present and future (Eichmann, 2019). Globalization and digitalization as a result of the 4.0 industrial revolution caused people to be surrounded by an increasingly complex environment and demanded many problems to be solved in personal life and at work (Fischer, Greiff, & Funke, 2012).

The characteristics of CPS are complex problems in a dynamic environment (Fischer et al., 2012), unstructured (Ahern, et. Al., 2014; Frank, et.al., 2018), uncertain (Amelung & Funke , 2013), not transparent (Herde, et. Al., 2016), unclear and interactivity (Eichmann, et al., 2019). The characteristics of CPS according to Funke (2010) are consisting of several variables that are highly interrelated and change over time (dynamic), the underlying connections are not transparent, and participants must achieve several objectives that are partly contradictory.

CPS skills need to be developed since school age. Efforts have been made to improve CPS skills through learning (Lai & Hwang, 2014; Öllinger, Hammon, von Grundherr, & Funke, 2015; Greiff, Wüstenberg, Goetz, Vainikainen, Hautamäki, & Bornstein, 2015). However, the development of CPS measurement instruments is dynamic. This is due to the fact that most of the test instruments are computer based (Sonnleitner et al., 2012, OECD, 2013).

Development of measurement instruments for CPS skills needs to be done. According to experts, CPS test results can be used to predict one's success in the future (Funke, 2010). This is because CPS correlates with one's intelligence (Sonnleitner, Keller, Martin, & Brunner, 2013). A person's ability to have an analogy has an important role when someone faces uncertainty in a complex problem (Chan, 2012). Therefore, many large companies run CPS tests to recruit

skilled workers. This is because, the problems faced in the real world are more complex when compared to the problems faced in the classroom (Stanujkic, et. Al., 2019). In addition, the company will solve a complex problem by prioritizing its resources (Caner, et. Al., 2017).

This study aims to conduct a literature review on measuring CPS skills. This study examines the instruments used to measure CPS skills in the past 10-15 years. In addition, this study also describes the indicators used in measuring CPS skills.

METHOD

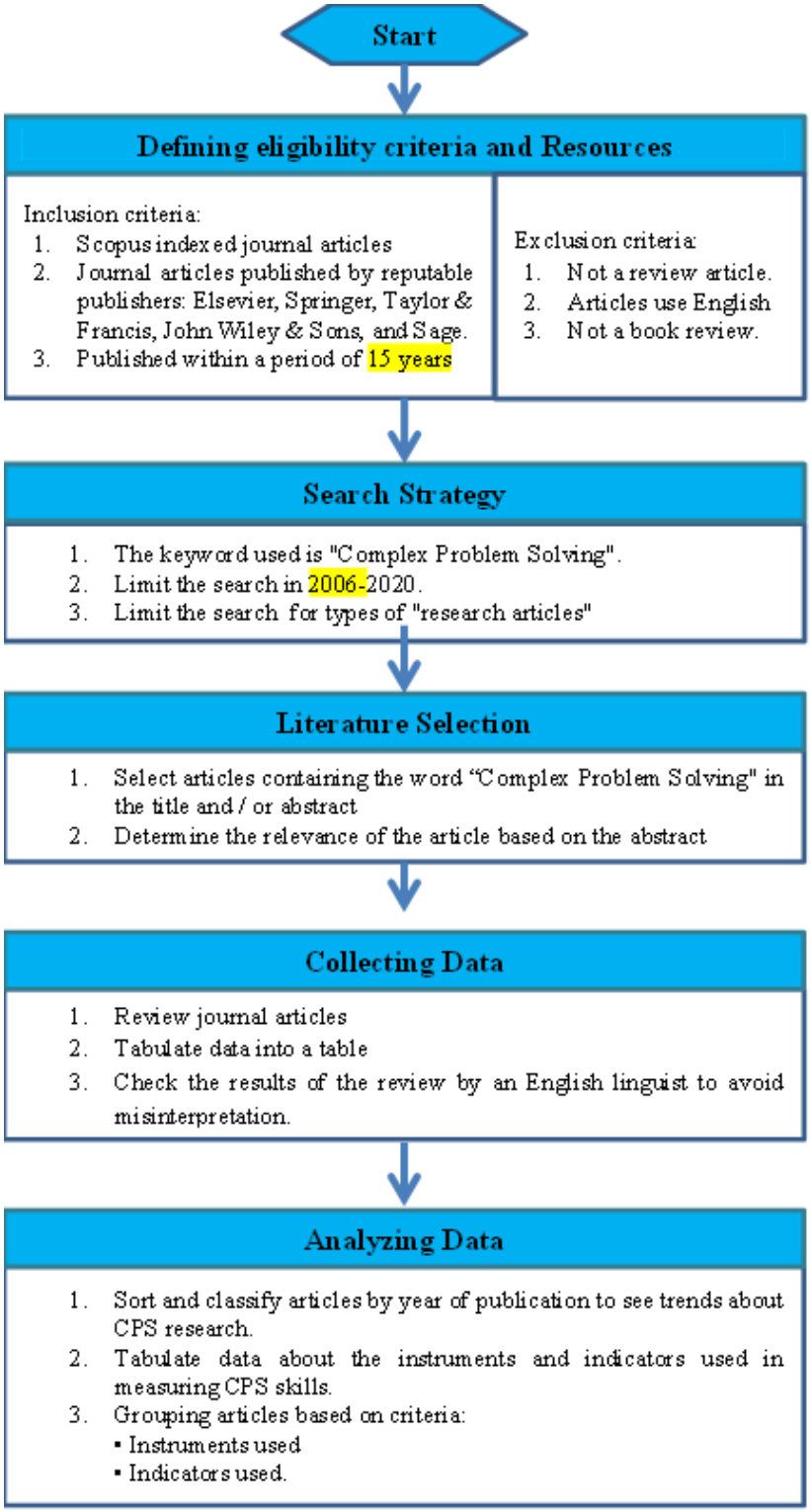

Figure 1. Research Stages

This study is a systematic literature review study that examines the measurement of CPS skills. The selection of systematic literature review research types is because this type of research uses strict criteria to select the articles to be reviewed. This is done to avoid the subjectivity of researchers. This study seeks to determine assessment techniques and indicators that have been used to measure CPS skills. Searching for an overview of the themes studied in relation to ongoing research is the aim of the literature review study (Oakley, 2012). Research literature review in this study is a systematic literature review that uses the principle of PRISMA. Stages of PRISMA include: Identification, Screening, Eligibility, and Included (Moher, Liberati, Tetzlaff, Altman, & Prisma Group, 2009). This stage of the study adapted the principle of PRISMA which can be seen in Figure 1.

Defining Eligibility Criteria and Information Sources

At this stage, the criteria for journal articles will be determined as sources of data. This article review uses reputable journal articles to obtain valid data. Inclusion criteria and exclusion criteria are used at this stage.

Inclusion criteria are used to limit the extent of the search to be performed. The inclusion criteria used in this study are as follows:

1. The article used is an article from a scopus indexed journal so that the data source obtained has a high level of validity.
2. To guarantee the reliability of the data, the source of the article comes from journals published by reputable publishers: Elsevier, Springer, Taylor & Francis, John Wiley & Sons, and Sage.
3. To ensure the novelty factor, the article used was published in the period 2006-present.

Exclusion criteria are used to limit what data sources should not be used. The exclusion criteria used in this study are as follows:

1. Review articles and book review articles are not used as data sources.
2. Articles use English.

Search Strategy

The keyword "complex problem solving" is used for searching. The article sought is limited to the type of "research article" article. Article search is limited from 2006 to present so that the article analyzed still has a novelty factor. Initially, this study limited articles published in the last ten years. However, the source of the data used was deemed insufficient (N = 70). Based on the principles of the snow ball sampling technique, the criteria for the expansion of the year are the longest published in 2006.

Literature Selection

At this stage the selection of articles to be used as a data source is done. Articles are selected based on the article title and / or abstract that contains the word "complex problem solving". Once downloaded, the articles are screened to see the relevance to the data needed. The number of articles reviewed was 76 journal articles. The article search flow chart adapted from PRISMA is presented in Figure 2.

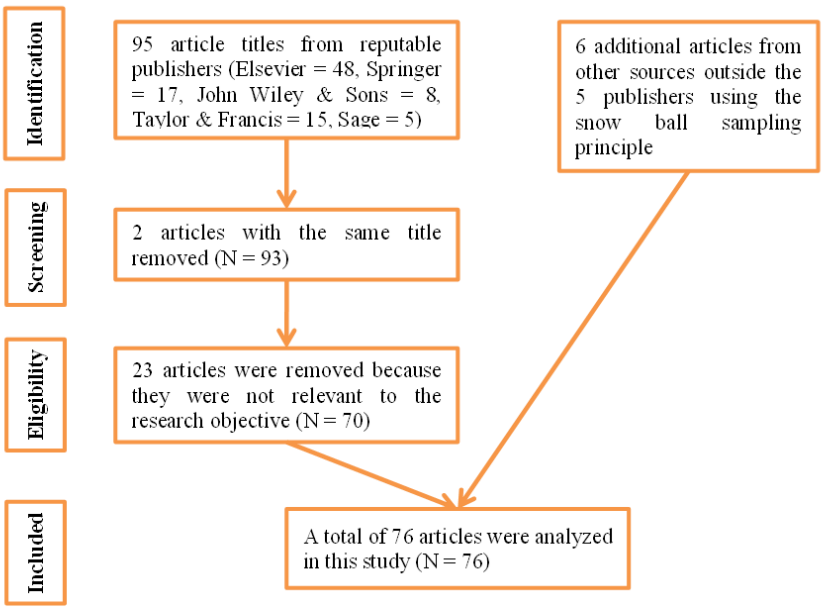

Figure 2. Article Selection Flow Chart

Data Collection

A total of 76 journal articles were reviewed by looking at their background, problems, objectives, research methods, results, and novelty and tabulated into tables. Two English experts examined the results of the review to ensure the validity of the results of the review article.

Data Analysis

Constant comparative methods (Boeije, 2002) are adopted for data analysis. The step of analysis of this method is to organize data, data reduction, categorization, synthesis, compile "working hypotheses". The analysis steps carried out in this study are as follows:

1. Data is organized by sorting and grouping articles by year of publication to see research trends on CPS.
2. Instrument and indicator data used in measuring CPS skills are tabulated.
3. Articles are grouped according to 1) the criteria for the instrument used to measure CPS and 2) the criteria for the CPS indicator used.
4. Journal article data is presented based on 1) the instrument used to measure CPS and 2) the CPS indicator used.
5. Synthesize trend measurement of CPS skills and trend indicator of CPS used.

RESULTS AND DISCUSSION

Research Trends about CPS

The journal articles analyzed in this study were sourced from reputable publishers (Elsevier, Springer, Taylor & Francis, John Wiley & Sons, and Sage). The publishers become a reference for world researchers, so that the results of the review can illustrate the results of research on CPS as a whole. Data on the number of journal articles analyzed by publisher can be seen in Figure 3.

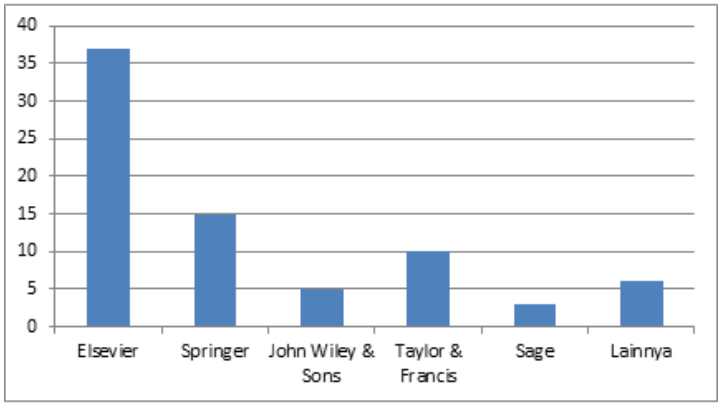

Figure. 3. Number of Journal Articles Based on the Publisher

Research on CPS experienced an increasing trend in 2011 to 2015. Research on CPS reached its peak in 2013. In recent years, the trend of the number of studies on CPS has not increased and has not decreased. It can be concluded that research on CPS is still a research trend. In fact, articles about CPS were found in the Elsevier database for the 2020 publishing year. Data of the analyzed articles are presented based on the year of publication in Figure 4.

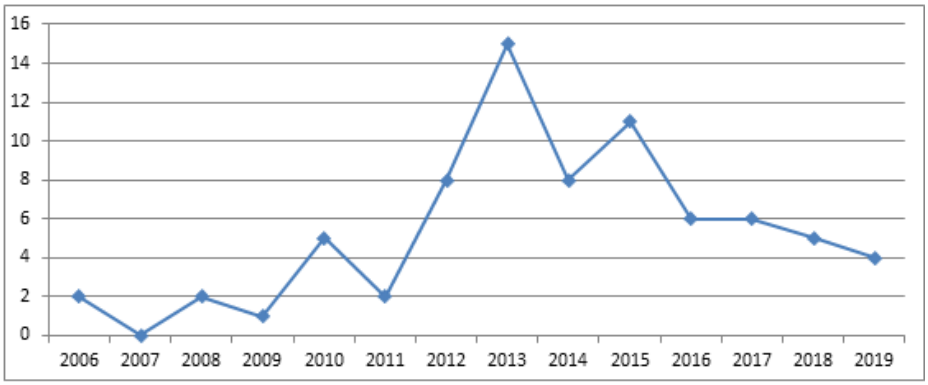

Figure. 4. Trends in Number of Research on CPS from Year to Year

CPS Skills Measurement Instrument

Most research on CPS uses measurement instruments in the form of MicroDYN (Greiff, et. Al., 2013a; Ederer, et. Al., 2016; Greiff, et. Al., 2013b; Wüstenberg, et. Al., 2014; Guss, et. , al., 2010, Wüstenberg, et al., 2012; Stadler, et al., 2015; Greiff, et al. 2013b, Lotz, et al., 2016; Rohe, et. al., 2016; Neubert & Fischer, 2015; Greiff, et al., 2015a; Schult, et. Al., 2017; Molnár, et. Al., 2018; Lotz, et. Al., 2017; Mainert, et. Al., 2015 ; Greiff & Neubert, 2014; Meißner, et al., 2016; Ederer, et. Al., 2015; Greiff, et. Al., 2015b; Mainert, et. Al., 2019; Stadler, et. Al., 2018; Greiff, et. Al., 2016; Rudolph, et. Al., 2017; Rudolph, et. Al., 2018; Schweizer, et. Al., 2013; Greiff, et. Al., 2014; Funke, 2009), MicroFIN (Ederer, et. Al., 2016; Greiff, et. Al., 2013; Guss, et. Al., 2010; Rohe, et. Al., 2016; Neubert & Fischer, 2015; Greiff, et. al., 2015a; Baggen, et. al., 2015; Ederer, et. al., 2015; Greiff, et. al., 2015b; Mainert, et. al., 2019), Tailorshop (Enge lhart, et. al., 2013; Meyer & Scholl, 2009; Greiff, et. al., 2015b; Funke, 2009), and Genetics Lab (Sonnleitner et al., 2012, Sonnleitner et al., 2013, Stadler, et. Al., 2015). MicroDYN, MicroFIN, Tailorshop and Genetics Lab are computer-based CPS tests. All four are widely used because they can meet the main requirements of a CPS test, which is a dynamic test (Fischer et al., 2012; Funke 2010). The test for measuring CPS is usually a computer-based test (Sonnleitner et al., 2012, OECD, 2013).

In addition to the three CPS test instruments above, there are several CPS test instruments that can be used, for example the Lohhausen paradigm (Ragni & Löffler, 2010), PISA tests (Dindar, 2018; Eichman, et. al., 2019), ColorSim (Kretzschmar, & Süß, 2015), McLarin Adventures (Eseryel, et. al., 2011; Eseryel, et. al., 2013; Daniz, et. al., 2013), problems in the environment virtual (Scherer & Tiemann, 2014), WINFIRE (Güss, 2011), COLDSTORE (Güss, 2011), Thought-Provoking Tasks (TPTs) (vanVelzen, 2017), predicting object weight (Dandurand, et., 2012) FSYS (Wolf & Mieg, 2010; Stadler, et al. '2015), Tower of London (ToL) (Unterrainer, et. Al., 2008), Semantics Effect (Goode & Jens, 2010; Beckmann, & Goode, 2014), the computer-simulated scenario "heating oil company" (Hagemann, et. al., 2008), convergent approaches (Zheng, & Cook, 2012), and DESIGMA (Christ, et. al., 2019). In addition, there are CPS measurements of the performance of performing tasks using an IT application, such as Mode-It (Angeli, & Valanides, 2013) and PubMed (Mirel, et. Al., 2012).

In addition to using computer-based tests, CPS can also be measured using paper-based tests. Kim (2012a), Kim (2012b), Kim, et. al., (2013) and Kim (2015) measure CPS skills by requesting a response of at least 350 words to a complex problem, then analyzed by T-MITOCAR. Kim, Park, Moore, & Varma (2013) measure CPS with performance appraisal combined with Model-Eliciting Activities.

Based on the data above, there are many CPS measurement instruments. Most CPS measurement instruments are computer based. The percentage of computer-based compared to paper-based CPS measurement instruments is presented in Figure 5a. Some of the computer-based CPS measurement instruments are Microworld-based CPS tests. The percentage of computer-based tests that use Microworld with others is presented in Figure 5b. The test-based instrument data used in the CPS measurement is presented in Figure 5c.

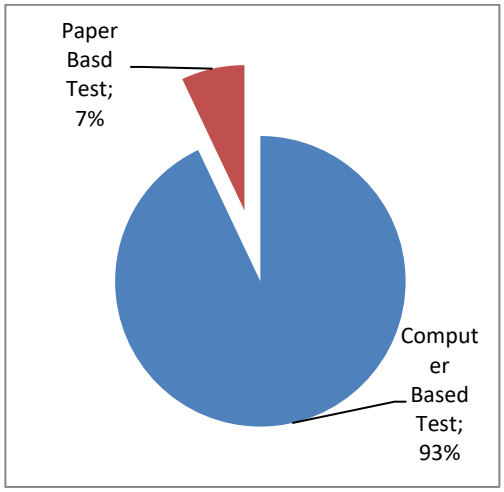

Figure. 5a

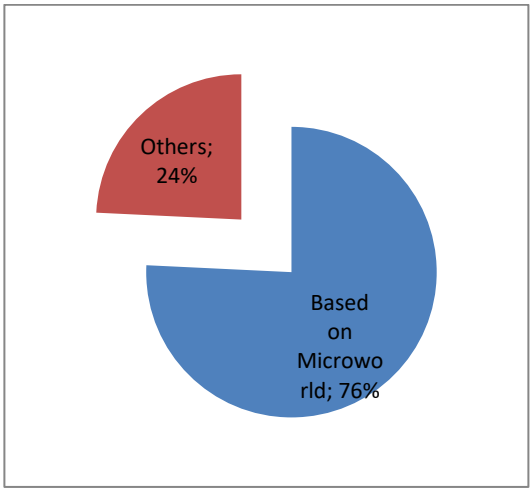

Figure. 5b

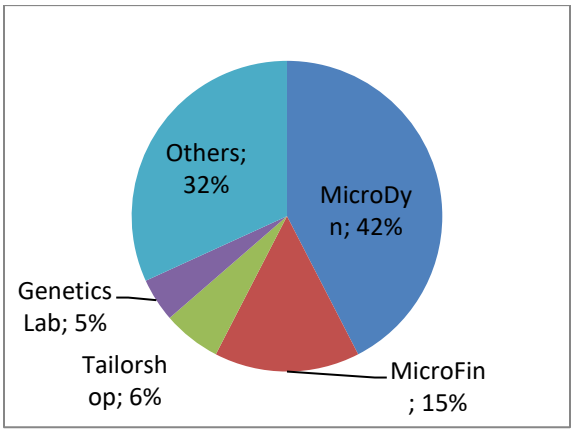

Figure. 5c

Fig. 5: a. Test of CPS; b. Computer Based Test based on Microworld of CPS; c. Computer Based Test based of CPS

CPS Skills Indicator

Based on the results of the review, it can be concluded that there is no certain standard in the use of CPS skill indicators. The CPS indicators used by the researchers are adjusted to the research theme. Baggen, et. al. (2015) that links CPS with entrepreneurship using CPS indicators relating to entrepreneurship, namely: views on opportunities in the industrial environment, social networks, self-confidence, and qualified knowledge. Stadler, et. al. (2015) which uses CPS indicators related to intelligence because they take the theme of intelligence associated with CPS. Hummel et. al. (2006) used problems in the context of justice to train CPS in law study students. vanVelzen (2017) uses language-related reasoning indicators for language research relating to CPS in the field of language. Rudolph, et. al. (2017) used CPS indicators related to metacognition to examine the association of CPS with metacognition. Various studies use practical views in CPS skill indicator theory. A person who successfully completes the specified task will be said to have an indication of the CPS skills with regard to time spent on the work and activities during the work.

Cooke & Kemeny (2017) argue that in the industrial world, CPS skills is influenced by creativity, innovation skills, problem-solving skills, level of education, science, technology and mathematical reasoning. On a practical level, the steps of solving complex problems include problem identification and concept, problem analysis and study, problem synthesis and modeling, solution proposition and definition, prototyping and test solutions, solution implementations, and solution maintenance (Elia & Margherita, 2018). CPS which was originally born from the industrial world, can adopt the above indicators for use in other fields of research.

CONCLUSION

Based on the results and discussion, it can be concluded that most of the CPS measurement instruments in journal articles reviewed use a computer-based test. A computer-based CPS measurement test was chosen because it can simulate a dynamic environment. The CPS studies reviewed did not use certain CPS indicators and became a standard. The CPS indicators used are adjusted to the research theme being carried out.

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