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Digital Teaching Materials using Comprehensive Mathematics Instruction Model for Interactive Mathematics Learning

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Abstract: The Ministry of Education and Culture found that the Covid-19 pandemic had caused a significant literacy and numeracy learning loss. The comprehensive mathematics instruction (CMI) model has a pedagogical prescription that is proven to be effective in improving students' mathematical thinking skills. This model can be developed into a digital teaching material that can support interactive learning. This study aims to build digital teaching materials using the CMI model that can support interactive mathematics learning. The research method used is research and development (R & D). The results of this study are in the form of a product named CMI Agent which is the result of the transformation of the CMI model teaching materials into LMS-based digital technology with interactive designs. Based on the studies that have been carried out, it is concluded that CMI Agent can support interactive mathematics learning.

Keywords: comprehensive mathematics instruction, teaching materials, research and development.

Abstrak: *Kemdikbudristek menemukan bahwa pandemi Covid-19 telah menimbulkan kehilangan pembelajaran (learning loss) literasi dan numerasi yang signifikan. Model comprehensive mathematics instruction (CMI) memiliki preskripsi pedagosis yang terbukti efektiif dalam meningkatkan kemampuan mathematical thinking siswa. Model ini dapat dikembangkan menjadi sebuah bahan ajar digital yang dapat mendukung pembelajaran interaktif. Penelitian ini bertujuan untuk membangun bahan ajar digital menggunakan model CMI yang dapat mendukung pembelajaran matematika interaktif. Metode riset yang digunakan adalah research and development (R & D). Hasil penelitian ini berupa produk yang diberi nama CMI Agent yang merupakan hasil transformasi bahan ajar model CMI ke dalam teknologi digital berbasis LMS dengan desain interaktif. Berdasarkan kajian yang telah dilakukan diperoleh kesimpulan bahwa CMI Agent dapat mendukung pembelajaran matematika secara interaktif.*

Kata kunci: *pembelajaran matematika konstruktif, bahan ajar, penelitian dan pengembangan.*

▪ INTRODUCTION

The Covid-19 pandemic has changed the Indonesian economy into a digital technology-based economy. The education technology sector in Indonesia has filled the digital economy landscape (Limanseto, 2021). On the other hand, data from the Ministry of Education and Culture (2019) suggests that most high school students have not been able to solve high-order thinking skill, and the results of the 2018 PISA found that the mathematical literacy ranking of Indonesian students aged 15 years is in 74th position out of 79 countries participating in the PISA survey (OECD, 2019b). In fact, PISA results are a benchmark for countries in the world in measuring a country's economic progress. The Ministry of Education and Culture's research found that the

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Covid-19 pandemic has caused significant learning loss (Bureau of Cooperation and Public Relations, 2021). Learning recovery during the Covid-19 pandemic is important to reduce the impact of learning loss on students. Online learning is considered very helpful in carrying out learning during a pandemic. However, hybrid will become the new normal in the world of education (Data and Information Technology Center (Pusdatin), 2021). Hybrid learning is a combination of direct learning in class and online by utilizing existing technology (Ramdhani, Suharta, & Sudiarta, 2020).learning online has helped students a lot in improving their mathematical thinking skills (Minalti & Erita, 2021; Rachmadtullah, Nadiroh, Sumantri, & S, 2018; Susanto, 2021).

The 2015-2019 Ministry of Education and Culture Strategic Plan says that the program for international student assessment (PISA) is a reference for comparing the quality improvement of policy makers in Indonesia (Pratiwi, 2019). PISA has succeeded in encouraging changes to the Indonesian education curriculum, including the educational evaluation system which has changed to a national assessment. The national assessment measures two types of literacy, namely reading literacy and mathematical literacy (the term used in Indonesia is numeracy literacy) (Pusmenjar, 2020). PISA 2018 has added to the focus of the student digital literacy survey by providing additional questionnaires related to digital literacy (OECD, 2019a).

The comprehensive mathematics instruction (CMI) model is a learning model that provides pedagogical prescriptions for teachers to produce effective and interactive learning (Delima, 2020). The CMI model has three learning stages that are adapted to the cognitive structure of students, namely develop, solidify and practice (Delima, Kusumah, & Fatimah, 2019). All of these stages contain math assignments/problems that are arranged according to the cognitive structure of students in learning mathematics. Content in the form of math questions/assignments in the CMI model has proven effective in improving mathematical thinking (Delima, Kusumah, & Fatimah, 2021). Numerical literacy is a subset of mathematical thinking (Delima et al., 2021). Thus, this content can be developed into a digital teaching material that can support interactive learning and increase students' numeracy and digital literacy.

Currently,there are no innovative digital teaching materials for interactive mathematics learning that accommodate content that reinforces students' numeracy literacy. Therefore, efforts are needed to build digital teaching materials for interactive mathematics learning by using content in the form of math questions/tasks on the CMI model. This effort is important to carry out considering there is no certainty when the pandemic will end and hybrid is currently a learning model that is very possible to reduce the impact of the pandemic. This research aims to build digital teaching materials that can support interactive mathematics learning both directly and hybrid. This digital teaching material has the advantage of its novelty value because there are no digital teaching materials whose content focuses on material designed to develop students' numeracy literacy.

▪ METHOD

Participants

This study took the population of SMA/SMK/MA students in Subang district with the consideration that SMA/equivalent students are the generation that most influences the growth of Indonesia's digital economy sector. Samples were taken using a cluster

sampling technique of 530 students, clustering based on the type of school, namely SMA, SMK and MA.

Research Design and Procedures

The research method used is research and development (R & D) with the following steps (Gustiani, 2019; Otto et al., 2019): Collect information and research through group discussion (FGD) activities with students and high school/equivalent teachers in Subang Regency; Planning is carried out to design the structure of digital teaching materials using the CMI model called CMI Agent. This structure was created based on the results of the FGD in the previous step; Developing CMI Agent prototypes that can be operated digitally; Try out the CMI Agent prototype in a small group to find out the weaknesses of this prototype from the perspective of students and teachers; Fixed CMI Agent prototype based on data found in previous trials; Trial CMI Agent to see its performance in learning; Revision and addition of CMI Agent content; The revised CMI Agent pilot was tested again to ensure the feasibility of the CMI Agent in learning mathematics; The final revision of CMI Agent, the hope is that at this stage what will be done is no longer revision of content or system errors, in other words CMI Agent is ready for deployment; Dissemination of CMI to mathematics students and teachers in Subang Regency. This research was conducted in the period 22 October - 27 November 2022 in Subang, West Java.

Instrument

The instrument used is a questionnaire to assess the feasibility of the CMI Agent as a digital teaching material for interactive mathematics learning. This instrument consists of 12 statements related to the eligibility of CMI Agents in the form of a Likert scale with 5 answer choices (very good, good, enough, less, and very less). This instrument was adopted from Rachmadtullah et al. (2018). Positive responses from respondents were indicated by selecting 'very good' or 'good' answers, while negative responses were indicated by selecting 'very poor' or 'poor' answers. The following statements are in the questionnaire:

Table 1. Questionnaire used in this research

No	Statement	No	Statement
1	Initial view of CMI Agent	7	Understanding of the material after using the CMI Agent
2	Ease in starting a CMI Agent	8	Learning independence with the help of CMI Agent
3	Display images contained in the CMI Agent	9	Interest in learning by using CMI Agent
4	The language used in CMI Agent	10	Student motivation after participating in learning using CMI Agent
5	Ease of navigation in operating the CMI Agent	11	The scope of material contained in the CMI Agent
6	Availability and clear instructions for using CMI Agent	12	The implementation of differentiated learning in CMI Agent

This instrument has been validated using the Spearman rho correlation test with the rho coefficient value of each statement item in the questionnaire in the range of 0.60-0.76. Meanwhile, the r-table value for the Spearman correlation rho (with α=0,05 and n=48) is 0.29. This shows that each question item has a rho > r-table value, so it can be said that each instrument is valid. Cronbach's alpha coefficient value obtained from the calculation results is 0.88. The data shows that the reliability of the instrument is in the high category. Thus, this questionnaire is valid to be used as an instrument in measuring the feasibility of a CMI agent.

Data Analysis

Data from the results of filling out the questionnaire by respondents were analyzed using descriptive statistics (percentage of respondents' answers). Data analysis was carried out by looking at the percentage of positive and negative responses from respondents. If there are no more negative responses, then CMI Agent is said to be appropriate to be used as an interactive mathematics learning medium.

▪ RESULT AND DISSCUSSION

This research was initiated by gathering information through FGD activities. The FGD aims to equalize perceptions about mathematics teaching materials using the CMI model which is integrated into a digital platform owned by PT Data Intelligent Indonesia. The FGD involved 40 high school students and 10 math teachers in Subang Regency. Students and teachers act as parties who will receive benefits from the CMI Agent as a CMI Agent for learning mathematics which assists teachers in improving students' digital literacy and numeracy. The results of the FGD are the collection of materials for customizing the CMI Agent platform based on input from students and teachers.

The next step is the CMI Agent construction planning. This planning was carried out together with PT Data Smart Indonesia as a partner in developing the CMI Agent digital platform. The CMI Agent construction process was carried out by taking into account the results of the needs analysis obtained from the FGD. Documentation of the development of each construction progress is discussed regularly through online meetings between the University of Subang and PT Data Smart Indonesia. CMI Agent is constructed with the architecture showed in Figure 1.

The planning stage produces a CMI Agent prototype. The resulting CMI Agent prototype is a learning management system (LMS) based platform. The use of the LMS platform is due to a number of studies suggesting that LMS is effectively used to support interactive learning (Lonto, Delly, & Rorimpandey, 2021; Yana, 2019). Each teaching material in CMI Agent is arranged in the form of a quiz following the syntax of the CMI model, namely the develop, solidify, and practice. Teaching materials in the form of quizzes at LMS have been shown to be effective in increasing student learning outcomes (Gamage, Ayres, Behrend, & Smith, 2019; Morera, Azofra, & Hernandez, 2012). Students can start learning any teaching material at the develop. However, the solidify can only be worked on, if the student has completed (or marked completion) at the develop. Likewise with the practice. Students can work on the practice, if they have completed (or given a completion mark) the solidify.

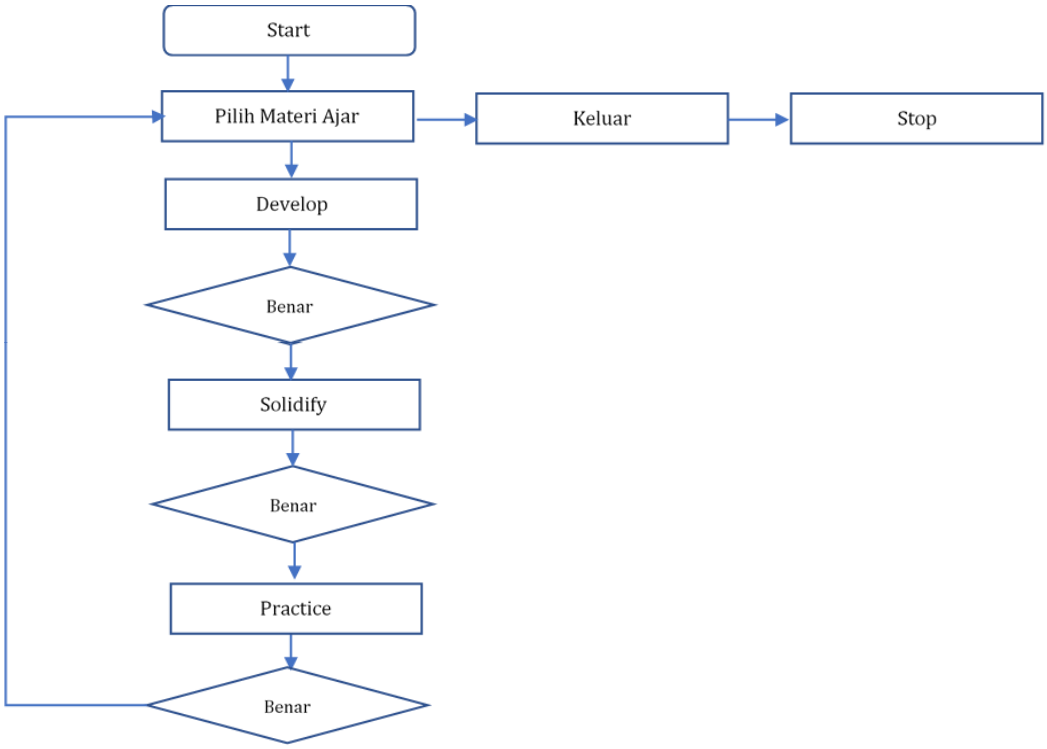

Figure 1. CMI agent architecture

There are five types of questions in CMI Agent, namely

1. Essays in the form of open-ended questions (questions with various answers/solutions). In accordance with the syntax of the CMI model, questions at the develop use the form of open-ended (Delima et al., 2019). Students can type answers directly in the answer column provided or upload answers (which have been written on other media) in the column provided and the teacher can check each student's work through the teacher's account.
2. Multiple choice with one correct answer, students can choose one correct answer by clicking on the box to the left of the correct answer.
3. Multiple choice with multiple correct answers, students can select multiple correct answers by clicking on the box to the left of the correct answer.
4. True and False, students must determine the truth value (True / False) of the statement in the problem.
5. Matching, students are asked to choose a partner for each element provided in the problem.

CMI Agent can be accessed via the link https://cmi-us.datacerdas.id/. The CMI Agent initial display shows the available course menu. Teachers who already have an account (teacher) can add to this page with their work in learning, both in the form of videos and other learning materials.

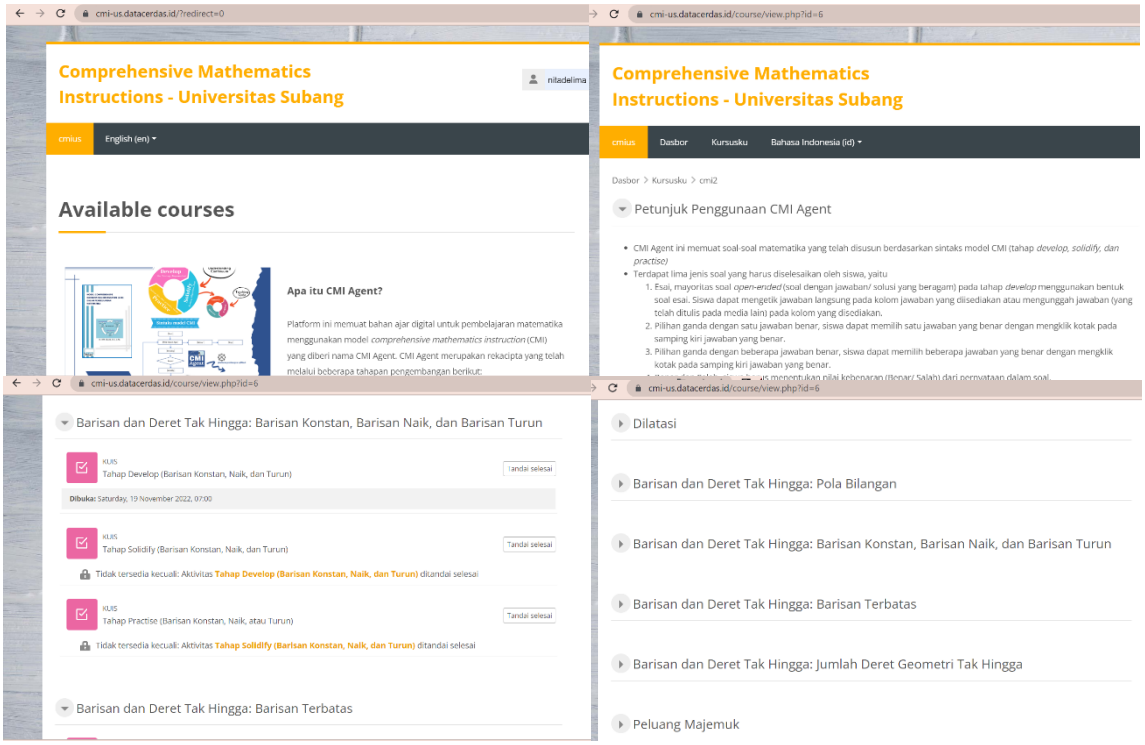

Figure 2. CMI agent prototype

Figure 2 shows the interface of the CMI Agent prototype. At the interface, a review is given regarding the introduction of the CMI Agent and how to carry out learning using the CMI Agent. The LMS-based CMI Agent platform can be accessed via a computer or smartphone without being limited by space and time and has proven effective in online (Duangjai & Rutaikarn, 2019; Keržič, Aristovnik, Tomaževič, & Umek, 2017; López-Tocón, 2021). Considering that the pandemic has not yet been declared over, CMI Agent is an effective learning innovation to assist students and teachers in learning mathematics, both directly and hybrid. The resulting prototype contains math teaching materials in SMA/equivalent.

The CMI Agent prototype was tested in small groups (limited) to 40 high school students and 10 math teachers in Subang Regency. This trial aims to find out the weaknesses of the CMI Agent from the point of view of high school students and teachers. The test results showed that the percentage of respondents' answers to the CMI Agent assessment was 58% good, 2% very good, 38% sufficient and 2% less. This shows that more than half of the participants gave a positive response (58% good and 2% very good) on the CMI Agent feasibility assessment. Even though more than half of the respondents gave positive assessment results, there were still respondents who gave negative responses. Several suggestions were given by respondents to improve CMI Agent, including the absence of instructions for use and the absence of direct feedback from the platform without having to wait for the teacher's response. This suggestion became material for improving the CMI Agent prototype.

The repaired CMI Agent was then tested again (Trial II) on 50 SMA students, 50 SMK students, 50 MA students, 10 SMA teachers, 10 SMK teachers, and 10 MA teachers, a total of 180 respondents. The survey results showed that the percentage of answers Respondents have a CMI Agent rating of 67% good, 17% very good, 14% sufficient, and 2% less. There was an increase in the percentage of positive responses (67% good and 17% very good), when compared to the previous trial.

The positive response increase in trial II was 24% from the previous results. This indicates that the CMI Agent revision has succeeded in improving its performance. Even so, the trial participants still complained about a number of things related to the limited content of CMI Agent. The next improvement is to add CMI Agent content, one of which is in the form of 2012 PISA questions. Adding content in the form of modified 2012 PISA questions to the CMI model syntax aims to assist students in developing numeracy literacy. Numerical literacy ability is a basic ability that every student must have to support his welfare in the future (Meeks, Kemp, & Stephenson, 2014; Wyatt-Smith, Gunn, & Elkins, 2011). The results of CMI Agent's assessment in trial III showed that the percentage of respondents' answers was 65% good, 14% very good, 21% sufficient, and there were no more respondents who chose less or very less answers. 79% of respondents gave a positive response (65% good, 14% very good) to CMI Agent. Thus, CMI Agent has met the criteria to become an interactive mathematics learning media. The final revision of the CMI Agent is adding an identity to the CMI Agent view. This identity addition aims to provide information to CMI Agent users about the owner and creator of this platform.

The next step is the dissemination of CMI Agent to high school, vocational high school, MA mathematics students and teachers in Subang district. This dissemination was carried out in three different days with a time of 8 hours/day, ie.

1. Dissemination I was held on November 20 2022 for high school teachers and students with 100 students and 20 teachers participating.
2. Dissemination II was held on 26 November 2022 for teachers and students of SMK with 100 students and 20 teachers participating.
3. Dissemination III was held on November 27 2022 for MA teachers and students with 100 students and 20 teachers participating.

The dissemination included presentations on CMI Agents, CMI Agent simulations, practice using CMI Agents for students and teachers. The presentation aims to provide an overview of the CMI Agent, the advantages of the CMI Agent, and the benefits of the CMI Agent in supporting interactive mathematics learning. The simulation activity provides an explanation to students and teachers on how to use the CMI Agent. After going through these two stages of activity, students and teachers directly practice using the CMI Agent, exploring every teaching material provided.

CMI Agent is the result of transforming CMI model teaching materials into LMS-based digital technology with interactive designs. The use of technology is very helpful in carrying out learning during the Covid-19 pandemic (Pakpahan & Fitriani, 2020; Rajan & Manyala, 2021). This is supported by the fact that the current generation of students is very close to technology, making it easier to adapt to online (Hastini, Fahmi, & Lukito, 2020; Rahayu et al., 2022). The concept of e-learning that utilizes technology

has been declared effective in increasing students' digital literacy (Amri, Jaelani, & Saputra, 2021; Setyaningsih, Abdullah, Prihantoro, & Hustinawaty, 2019; Tomczyk, 2020).

Figure 3. Practice using CMI agent

Even though the study from home (BDR) policy is no longer enforced, however, hybrid will become the new normal in the world of education (Keane, Linden, Hernandez-Martinez, & Molnar, 2022; Center for Data and Information Technology (Pusdatin), 2021). Thus, CMI Agent can become an hybrid that supports increasing digital literacy. The CMI model is an effective mathematics learning innovation in improving mathematical thinking (Delima et al., 2019, 2021). Numerical literacy is a component of mathematical thinking (Delima et al., 2019; Karadag, 2009; Stacey, 2006). CMI Agent is the digital form of the CMI model. Thus, CMI Agent will be able to help students improve their numeracy literacy.

▪ CONCLUSION

Based on the discussion above, it can be concluded that CMI Agent is a digital teaching material that can support mathematics learning in an *hybrid* interactive. This research has not revealed statistical facts about the effectiveness of CMI Agent in increasing students' numeracy literacy and digital literacy. Therefore, the authors recommend further research regarding the effectiveness of CMI agents in increasing students' numeracy and digital literacy.

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