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Application of Multirepresentation-Based Creative Problem-Solving Learning Models to Improve Critical and Creative Thinking Skills for Students

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Abstract: The 21st-century competencies students need to have include creative thinking skills, critical thinking skills, literacy, and numeracy. These competencies can be developed in the learning process in class explicitly. This research aims to analyze the effectiveness of the Multirepresentation Based Creative Problem-Solving (MBCPS) learning model in improving students' critical and creative thinking skills. The MBCPS Model Syntax consists of four stages: 1) problem identification, 2) finding ideas, 3) evaluating ideas with multiple representations (verbal, visual, and mathematical), and 4) validating solutions. The MBCPS model was applied to the experimental group and the Problem-Solving (PS) learning model in the comparison group on four study programs, natural science education. culinary education, public health science, and nutrition science with material on the science of nutrition. The difference between before and after learning was tested by Mann-Whitney, and N-gain tested the effectiveness. The results showed that before learning, there was no difference in critical and creative thinking skills, with a p-value > 0.05 between the experimental group and the comparison group. After learning, there was a very significant difference ($p < 0.05$). Learning the MBCPS model can improve critical thinking skills with an N-gain of 0.72 (high category) and creative thinking skills with an N-gain of 0.67 (medium category). The MBCPS learning model can be implemented on a broader scale according to the characteristics of complex course material to develop models in the field of education.

Keywords: *creative problem-solving; multirepresentation; critical thinking, creative thinking; nutrition.*

Introduction

Indicators of student quality include nutritional status in the form of malnutrition, namely, underweight, overweight, and obese. status of students in various countries, such as in Madrid is underweight 5%, overweight 16%, and obese 4% (Castelao-Naval et al., 2019), Cameroon medical students are underweight 4.9%, overweight 21.6%, and obesity 3.0%) (Bede et al., 2020). In Indonesia, the 2018 data is not much different; the percentage of young women aged 12-18 years who are stunted is 35.5%, consisting of very short 7.9% and short 27.6% (Kementerian Kesehatan RI, 2018). The findings on students. of the UNNES Faculty of Engineering underweight and overweight were 23.5% and 9.2% respectively (Fathonah, 2018).

In the following two years, malnutrition was 21.9%, and excess nutrition and obesity were 22.0% (Fathonah et al., 2020). The cause of malnutrition is poor diet (Lai et al., 2021; Smith, Disler, and Watson, 2020). Habits that many students from various studies related to eating patterns include not having breakfast (Bede et al., 2020; Chen et al., 2014; Mameli et al., 2014; Ministry of Health Indonesia, 2014; Mullan, 2014), fatty sausages/meat, industrial cakes, lean meat, and fish are consumed excessively (Castelao-Naval et al., 2019), low consumption of fruit, vegetables, and milk, high consumption of sweets, fried foods, and alcohol (Bede et al., 2020), consumes a lot of food fast food (Smith, Disler, and Watson, 2020), fluctuating eating patterns (Smith, Disler, and Watson, 2020), eating out habits (Lee et al., 2020). not under the body's nutritional needs (Castelao-Naval et al., 2019; Hashimoto, Inoue, snd Kuwano, 2020; Partida et al., 2018), and poor nutritional quality (Schroder, Fïto, and Covas, 2007). Most students

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from the faculties of medicine and nutrition in Mediterranean countries need to improve their knowledge about healthy eating habits (Antonopoulou et al., 2020).

Poor dietary conditions, poor literacy, and health literacy will have a negative impact on health, so awareness is needed and must be corrected (Henrique et al., 2019; Kalkan, 2019; Parekh et al., 2018). The Food and Agriculture Organization (FAO) wants everyone to have access to a diet that is adequate, diverse, healthy and safe (WHO, 2018). Various studies have been conducted to determine the importance of nutrition education. The active and healthy nutrition group scored higher on academic achievement test scores with reading, math, and science standards (Asigbee, Whitney, and Peterson, 2018). The highest average score for nutritional knowledge was obtained by respondents with a standard body mass index (BMI) (Całyniuk et al., 2019). Nutrition education is needed to support future doctors in the 21st century (Crowley, Ball, Hiddink, 2019). Nutrition improvement programs reduce the frequency and likelihood of illness and improve students' health status (Liang et al., 2022).

Based on several studies, the substance of nutrition is reported to constantly be developing (Sizer et al., 2020), both vertically and horizontally into the future (Hardinsyah, 2017). The nutritional problem is complex and characterized by many components, interrelationships, feedback, and dynamics (Schneider et al., 2011). In this study, the nutritional material is limited to balanced nutrition. Balanced nutrition is a nutritional guideline in Indonesia to maintain average body weight and prevent nutritional problems (Ministry of Health Indonesia, 2014). One that influences nutrition education is the learning process following the characteristics of nutritional problems and alternative solutions in learning nutrition and health with the Creative Problem-solving (CPS) learning model. According to Nazzal, the CPS learning model has four stages: problem identification, generating ideas, evaluating ideas, and validating solutions. Creative Problem-solving is a collective creative effort used by groups to solve problems (Kim, Choe, and Kaufman, 2019) and seek more original and more solutions (Hooijdonk et al., 2020). Well-executed Creative Problem-solving will encourage the development of higher-order thinking (Skeriene et al., 2020). For the learning process to be more meaningful, to have a deeper understanding of concepts, and to improve students' creative and critical thinking skills, an expansion of answers was carried out in evaluating ideas. The answers are not only verbal but added non-verbally, namely visually and mathematically. Answers with multiple representations are multi-representations (Angell, Guttersrud, and Henriksen, 2007). The combination of CPS learning with multi-representation is called the Multirepresentation-Based Creative Problem-solving (MBCPS) learning model (Fathonah et al., 2022). The MBCPS model that has been tested is expected to add to the innovative teaching model in the education sector, especially in the fields of nutrition. Improving the quality of learning can be done by implementing innovative learning models (Novkovic Cvetkovic and Stanojevic, 2017).

The results of the literature study show that nutrition and its problems are related to various fields of natural science or science nutrition, brain development, and cognitive function involving chemical reactions and human biological systems. Proper nutrition is essential for normal brain and neurocognitive development. Failure to optimize neurodevelopment early on can have profound long-term implications for mental health and quality of life (Kadosh et al., 2021). For normal neurocognitive development and to prevent its decline, adequate nutrition is needed throughout life (García et al., 2018; Kadosh et al., 2021), and reasonable stimulus efforts are needed (Muin et al., 2020). Nutrients are related to various chemical reactions in the field of food processing and their impact on health, including fats that are easily oxidized in various ways, such as thermal oxidation and air oxidation (Barden and Decker, 2016). Oxidized fats decrease the nutrition, taste, texture, and appearance of food, reduce food quality, shorten shelf life, and cause enormous economic losses (Barden and Decker, 2016). Consumption of fried foods is higher in people with coronary heart disease and acute myocardial infarction (Jin, G. U. O. et al., 2013). The research objectives were to analyze the effectiveness of Multirepresentation-Based Creative Problem-Solving Learning Balanced Nutrition to improve critical and creative thinking skills.

Materials and Methods

Research using research and development (R & D) methods are carried out to develop or validate educational and learning products (Stigler et al., 2020). The product developed is a multi-representation-based CPS learning model that includes RPS, Student Worksheets (SW), and data collection instruments equipped with Nutrition and Health textbooks. The research used the instructional design of the Analyze,

Design, Develop, Implement, and Evaluate (ADDIE) (Branch, 2009).

The program implementation phase is applied to the nutrition learning process with the experimental group (MBCPS) and the control. The learning model in the control group is the Problem-solving (PS) learning model. The learning activities observed are in line with the CPS syntax as reported by Nazzal and Kaufman (2020) which includes (1) problem identification, (2) idea generation, (3) idea evaluation, and (4) solution val-idation. In the evaluation stage, ideas are expressed in three representations of answers. The three representations of the answer are verbally, visually, and mathematically. Table 1 lists the syntax modifications of the MBCPS learning model previously reported by Nazzal and Kaufman (2020). The activities of students and lecturers as data sources at each stage of syntax are displayed. The experimental activity began with the lecturer's explanation of the objectives of MBCPS research and learning. The activities carried out by students in each pillar of balanced nutrition are 1) studying the material of each pillar of balanced nutrition, 2) studying problems according to the pillars, 3) working on MBCPS questions in groups with stages of problem identification, idea generation, idea evaluation with multirepresentation, and 4) solution validation, 5) listening to material explanations, 6) presenting the results of problems in class, 7) problem solving class discussions with MBCPS, and 8) the establishment of problem solutions. The activities carried out by lecturers are 1) explain each pillar with videos created with the Zoom app, with various examples of solving problems with the MBCPS model, 2) accompanying and guiding students both working individually and in groups, 3) observing discussion and presentation activities and 4) evaluating the results of solving problems with MBCPS and providing feedback. The support system for the application of the balanced nutrition MBCPS learning model is 1) learning tools in the form of Semester Learning Plans and Student Activity Sheets, and 2) learning media in the form of 5 learning videos, for the first video in the form of a learning model, and containing 4 videos containing 4 pillars of balanced nutrition; 3) MBCPS model balanced nutrition textbook entitled "Literasi Gizi Seim-bang dalam Pembelajaran Sains" with ISBN 978-623-02-3790-4 (Fathonah et al., 2022), 4) Research instruments include creatitive thinking skills and critical thinking skills, and 5) Other learning resources related to balanced nutrition material in the form of e-books, textbooks, and national and international journals. One example of the problem of CPSBM balanced nutrition on food diversity, presented in Appendix 1.

Table 1. *Multirepresentation Based Creatitive Problem Solving Learning Syntax on Four Learning Phases*

Four phases model CPSBM	Learning Activity Indicators
Problem identification	1) Looking at the concept of balanced nutrition that is difficult to understand, 2) Read carefully the problematic concept of balanced nutrition
Idea generation	1) Discovery of various kinds of ideas / alternative solutions according to theory, 2) Find a variety of appropriate balanced nutrition problem-solving techniques;
Idea evaluation	1) Determine the design of a specific and best solution 2) Present solutions with multirepresentation (verbal, visual, and mathematical) correctly
Solution validation	1) Implement the design of the best solution, 2) Compare solution design against standard values or sources (if present in the literature) 3) Re-examine the best solutions based on the right concepts

Sources: Nazzal and Kaufman (2020)

The research was conducted in four study programs, natural science education, culinary education, public health science and nutrition science, with 114 students as the experimental group and 113 students as the control group. Activities are divided into independent, structured, and face-to-face activities on campus. Independent activities are carried out at home for 120 minutes, structured activities in groups for 120 minutes, and face-to-face activities on campus for 100 minutes. Independent activities in MBCPS or PS are activities to work on student worksheets (SW) individually. Activities consist of studying the material

for each pillar, compiling problems, and solving problems according to the MBCPS and PS stages.

The results of independent activities are individual SW on each pillar of balanced nutrition. The individual student activity sheets are discussed in groups as a structured activity. The result of this activity is an SW, which will be discussed in class.

Face-to-face activities on campus are carried out jointly between students and lecturers offline. Student activities include listening to lecturers' explanations, presenting tasks of solving problems with MBCPS and discussing and improving according to input from other students and lecturers. Lecturer activities present material, observe presentation and discussion activities, evaluate and provide feedback.

Critical Thinking Skills is measured using a multiple-choice test instrument with reasons for the concept of balanced nutrition, according to the stages of the thinking process to solve problems correctly. The components of critical thinking studied include the skills to argue, the skills to make inferences (think deduction and induction), and the skills to evaluate, and make the best solution (Sani, 2018). Scoring is based on critical thinking steps using a scale of 1 - 4. Each component is composed of 5 questions, so that the maximum score for each component is equal to 20.

Creative thinking skills are measured by the Torrance Test of Creative Thinking (Kashani-Vahid et al., 2017). There are four indicators of TTCT, namely fluency, originality, flexibility, and elaboration, with four criteria. The indicator is associated with the MBCPS syntax. Each indicator is assessed with a score between 1 - 4. The creative thinking skills are assessed from the Student Worksheet instrument (4 problems), which is worked on individually and continued in groups and classes. Three assessors carried out the assessment.

The instruments used in the research have been subjected to content validation, construct validation, and reliability. Instruments that have been standardized are not tested for validity and reliability. Content validity was tested by Aiken's V (Aiken, 1985). The results of the content validity test showed that the AikensV value was above the acceptance limit > 0.80, which meant that the instrument was declared valid and feasible to use. Instrument reliability test with two odd and even questions tested for correlation with person correlation. The results of the instrument reliable test and correlations obtained are very high. Construct validity was tested by testing the personal correlation between each component and the variables (Bonamente, 2017). The test results show that the r value is above 0.5 and the p value > 0,05, meaning that all components are valid. Data analysis techniques to determine the effectiveness of MBCPS learning use N-gain (<g>) (Fadaei, 2019). The data normality test obtained abnormal results, so the analysis used was Mann-Whitney (Kirch, 2008).

Results

Students have the skills to think critically at the same level in the PS and MBCPS groups at the beginning of learning and are not significantly different (p> 0.05). Table 2 shows that MBCPS and PS learning can improve all indicators of critical thinking skills, as shown by the scores achieved. The increase in the average score in the MBCPS group was 15 points, while the PS group increased by 6.7. The Mann-Whitney yields p = 0.000, which is very significantly different. The results are the same as those on all indicators of critical thinking skills.

Table 2. *Results of Assessment and Test of Differences in Critical Thinking Skills*

Critical thinking skills Indicator	Before learning		*p*	After learning		p
	PS groups	MBCPS groups		PS groups	MBCPS groups	
Analytical skills	16.4	16.5	0.399*	18.3	19.6	0.000**
Inference skills	14.8	15.1	0.109*	16.3	19.0	0.000**
Evaluation skills	14.2	14.3	0.115*	15.7	18.4	0.000**
Decision making skills	13.4	13.4	0.974*	15.1	17.3	0.000**
Critical thinking skills	58.7	59.2	0.082*	65.4	74.2	0.000**

Note: * there was no difference between the PS group and the MBCPS group

** there was a difference between the PS group and the MBCPS group

The increase in students' critical thinking skills occurred in both the PS group and the MBCPS group. However, the increase was higher in the MBCPS group. This is shown from the N-gain value of critical thinking skills in the MBCPS group 0.72 (high category) and the PS group 0.31 (medium category), presented in Figure 1. The research results obtained showed that critical thinking skills increased significantly and were strongly supported by the implementation of MBCPS with stages that were carried out effectively. Students experience a more manageable way when using multiple representation forms in understanding the concept of balanced nutrition. The decision-making procedure is preceded by critical and creative thinking, followed by an assessment thinking step by considering the best method and/or criteria and determining the decision taken by the student. In the two PS and MBCPS groups, the increase in decision-making skills was the lowest with the low and medium N-gain category.

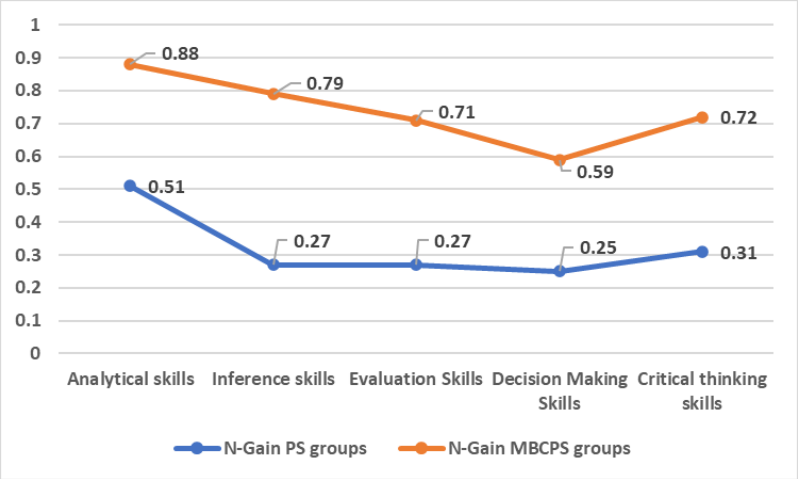

Figure 1. Effectiveness Test of Critical Thinking Skills in PS and MBCPS Groups

A different test was carried out on students' creative thinking abilities at the beginning, before, and after learning to find out the effectiveness of learning. For all indicators of creative thinking skills, the mean was obtained between the PS group with a score of 11.3 - 14.6 and the MBCPS group, slightly higher with a score between 11.6 -14.1, in full, as seen in Table 3. The results of the different tests showed no difference in all indicators with a p-value > 0.05, both in the PS and MBCPS groups. In contrast, after learning, the results showed a significant difference between the PS and MBCPS groups with a $p < 0.000$. These results show that MBCPS learning can effectively be used as a balanced nutrition learning model. The difference was that balanced nutrition problems were self-made individually, and the control group was given a problem-solving learning model.

Table 3. *Results of the Assessment and Test of Differences in Creative Thinking Skill*

Creative thinking skill Indicator	Before learning		p	After learning		p
	PS Group	MBCPS group		PS group	MBCPS group	
Fluency	14.6	14.1	0.099*	24.5	30.1	0.000**
Originality	12.3	12.2	0.170*	20.7	27.6	0.000**
Flexibility	11.3	11.6	0.759*	17.9	24.4	0.000**
Elaboration	11.7	12.0	0.249*	15.4	20.2	0.000**
Creative thinking skill	50.0	50.0	0.618*	78.5	102.3	0.000**

Note: * there was no difference between the PS group and the MBCPS group

** there was a difference between the PS group and the MBCPS group

The creative thinking skills, including all the indicators for the PS and MBCPS groups, did not differ before the learning model treatment but significantly differed afterward. This shows that the two groups experienced increased creative thinking skills. However, its effectiveness in the MBCPS group was higher than in the PS group. Overall, N-gain after MBCPS learning can increase creative thinking abilities in the medium category (0.67). The N-gain indicators of fluency and originality in the high category are 0.90 and 0.78 respectively (Figure 2). Meanwhile, N-gain in the flexibility and elaboration indicators is in the medium category. Effectiveness with PS learning is lower than MBCPS, with indicators of fluency, originality, and flexibility in the medium category, with N-gain between 0.31 - 0.56, and even elaboration in the low category.

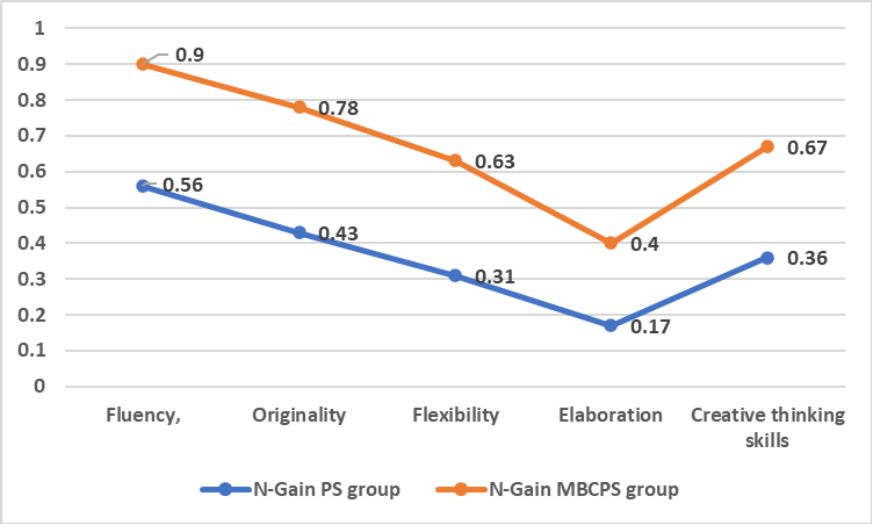

Figure 2. Effectiveness Test of the Creative Thinking Skill of the PS and MBCPS Groups

Discussions

The creative thinking skills, including all the indicators for the PS and MBCPS groups, did not differ before the learning model treatment but significantly differed afterward. This shows that the two groups experienced increased critical thinking skills (Table 2) and creative thinking skills (Table 3). However, its effectiveness in the MBCPS group was higher than in the PS group. The N-gain value was more significant in the MBCPS group. The MBCPS group was trained to look for different alternative answers (at least three answers), so they had to read a lot and understand various learning resources. It trains fluency in generating lots of ideas and originality in finding solutions to problems that are relevant and original. Students make inferences by developing ideas relevant to the problem and evaluate by assessing solid arguments and evidence in determining solutions. However, to get an alternative answer takes time. The

time spent searching for additional information, the amount of information viewed, and the extent of the information search mediated the relationship between problem construction engagement and creativity across categories. Furthermore, the relationship between information search efficiency and creativity depends on the involvement of problem constructs. For people involved in problem construction, the more efficient the search for information, the more creative the solutions (Harms, Reiter-Palmon, and Derrick, 2020). The increase in N-gain for the two indicators received the most significant value, with the high category. There were only two alternatives in the PS group at the solution planning stage, so the fluency and originality skills needed to be higher. Searching for a lot and variety of information trains students' inference and literacy skills to be increasingly honed. In addition, the activities of the lecturers in the learning process support this achievement. These activities include mentoring and mentoring students working individually and in groups in working on SW, evaluating the results of problem-solving, and providing feedback and input, especially in determining alternative solutions and visualizing verbal answers in pictures. This makes the skills to think continue to grow to be more perfect.

Three indicators of critical thinking skills (Figure 1), namely analytical skills, inference skills, and evaluation skills, are in the high category (N-gain > 0.70). These results show that the MBCPS model is more effective in improving students' critical thinking skills than the PS model. Students can analyze, inference, and evaluate nutritional problems well in the high category. Various previous studies have shown the same results, namely that the application of learning models can improve critical thinking skills, among other things Android-based media in Androwebic and E-Bokartumban (Isnaeni, Sujatmiko, and Pujiasih, 2021), reflective inquiry learning (Verawati et al., 2021), Problem-based interactive physics e-modules (Sujanem and Suwindra 2023), Learning Strategy "Students as Researchers" (Daryanes et al., 2023). Flipped classroom learning based on disaster map visualization (Astawa et al., 2022) and flipped Classroom-Based Project Assessment (Rapi et al., 2022) influence critical thinking skills.

Developing critical thinking skills is based on Piaget's cognitive theory when students individually explore or look for solutions to answer assigned problems. In Piaget's theory, exploring and building knowledge means understanding and internalizing knowledge within themselves. When students work in groups, which is based on Vygotsky's theory, they present individual ideas. During discussions, they are able to produce interference of ideas so that the correct theoretical formula and the best solution can be obtained (Nazzal et al., 2020). Thinking students focus on the core of the problem and think deeply so that they do not produce biased thought products or deviate from correct concepts and theories in determining solutions to problems. Apart from that, students can also think sharply about problems, and students can find solutions that are narrow enough so that they get the right solution (Kim et al., 2019).

Multirepresentation-based CPS learning has advantages in the ability to analyze and generate ideas based on the problem being studied (at the problem identification and idea generation stage). They convey the selected and best ideas as problem-solution designs based on collaborative activities and helping each other in active learning activities (Laughlin et al., 2006). The development of critical thinking is shown in determining the most appropriate solution plan and effective procedural strategy in solving problems, namely choosing the formula for the theory of balanced nutrition with the appearance of the material in a multi-representational manner (visual/pictures, mathematics, graphics) which is applied following the theory of balanced nutrition by students (solution assessment).

Students apply the principle of sharing knowledge and experience (Mayseless, Hawthorne, and Reiss, 2019; Sophonhiranraka, Suwannatthachoteb, and Ngudgratokec, 2015), and discuss developing students' thinking to be logical and reasoned (Al-Tabany, 2015). Students' critical thinking skills have been developed through solving balanced nutrition problems using convergent thinking patterns. Students' ability to make conclusions and solve problems is necessary and supports the mastery of concepts (Sani, 2019).

Students process data and information from various points of view to make the most appropriate nutritional decisions. Students also use nutritional standards from applicable national and international regulations to answer problems by complying with scientific principles (solution validation). The critical thinking skills students had developed during MBCPS learning in the experimental group were not facilitated in learning for the control group with conventional problem-solving learning. MBCPS learning involves students exchanging skills and experiences between individuals in one group (O'Neil, Chuang and Baker, 2009).

The research results obtained showed that critical thinking skills increased significantly (Table 2)

and were strongly supported by the implementation of MBCPS with stages that were carried out effectively. Students experience a more manageable way when using multiple representation forms in understanding the concept of balanced nutrition. The decision-making procedure is preceded by critical and creative thinking, followed by an assessment thinking step by considering the best method and/or criteria and determining the decision taken by the student. In the two PS and MBCPS groups, the increase in decision-making skills was the lowest with the low N-gain category. This happens because decision-making is a complex and challenging process that requires training (Ahmady and Shahbazi, 2020), emotional stability, and caution (Hough, 2020). The challenge in decision-making is determining priority criteria and using appropriate decision-making strategies. The cognitive knowledge required is scientific knowledge and scientific epistemological beliefs (Fang, Hsu, and Lin, 2019). Judgmental thinking uses arguments with information claims and/or scientific evidence. Making decisions is high-level thinking at the top level. Therefore, it requires complex, focused, deep thinking (Butterworth et al., 2013).

Several previous studies support the results of this study. Well-executed Creative Problem-solving will encourage the development of higher-order thinking (Skeriene et al., 2020). High-order thinking includes creative thinking and critical thinking skills (Sani et al., 2019; Tawil and Liliasari, 2013), problem-solving, and decision-making (Tawil and Liliasari 2013), and Multiple Skill Laboratory Activity Module (Malik and Ubaidillah, 2020). Besides that, the instructional design used by ADDIE supports learning effectiveness. The same research results show that training with ADDIE can improve creative skills (Shahat, Gaber, and Aldawsari, 2023). In the MBCPS and PS learning models, practice is carried out in expressing various ideas or information (convergent thinking) and deciding the best solution (divergent thinking). Divergent and convergent thinking that is carried out together during various phases of problem-solving can produce better solutions (Shettar, Vijaylakshmi, and Tewari, 2020).

The average N-gain obtained on all indicators of critical thinking skills in the MBCPS group was higher than the PS group. This shows that MBCPS learning is efficacious in improving critical thinking skills. Overall, the effectiveness of creative thinking skills in MBCPS learning increases in the high category, with an N-gain of 0.72, presented in Figure 2. In the early stages of learning, students are trained to create and solve problems on each pillar individually. Arranging problems means students create conflicts that must be resolved. This can encourage curiosity and high voluntary interest (Merrotsy, 2017). Practice making problems and solving them individually requires good initial knowledge of the concepts of balanced nutrition. Students carry out activities by reading and understanding the textbooks given. Through “deliberate practice” at each level (Deslauriers, Schelew, and Wieman, 2011), students can acquire the necessary knowledge and skills to become better problem solvers (Mahalingam and Fasella, 2017).

Making MBCPS and PM problems is done individually and continued as a group. In groups of five to seven, members can share ideas. The goals in group learning include: 1) students have positive interactions with the thoughts and feelings of their peers (Kim et al., 2019). 2) emphasizing cooperative activities and mutual assistance in learning activities (Gerace et al., 2005; Laughlin et al., 2006), 3) applying the principle of sharing knowledge and experience (Mayseless et al., 2019; Sophonhiranraka et al., 2015), 4) discussions that will help students thinking become logical (Al-Tabany, 2015), and 5) involve exchanging abilities and experiences between individuals in a group (O’Neil, et al., 2014), developing critical thinking skills (Chou, Wu, and Tsai, 2019; Kim et al., 2019; Nazzal et al., 2020).

The creative thinking skills, including all the indicators for the PS and MBCPS groups, did not differ before the learning model treatment but significantly differed afterward. This shows that the two groups experienced increased creative and critical thinking skills. However, its effectiveness in the MBCPS group was higher than in the PS group. The N-gain value was more significant in the MBCPS group. The MBCPS group was trained to look for different alternative answers (at least three answers), so they had to read a lot and understand various learning resources. It trains fluency in generating lots of ideas and originality in finding solutions to problems that are relevant and original. Students make inferences by developing ideas relevant to the problem and evaluate by assessing solid arguments and evidence in determining solutions. However, to get an alternative answer takes time. The time spent searching for additional information, the amount of information viewed, and the extent of the information search mediated the relationship between problem construction engagement and creativity across categories. Furthermore, the relationship between information search efficiency and creativity depends on the involvement of problem

constructs. For people involved in problem construction, the more efficient the search for information, the more creative the solutions (Harms, Reiter-Palmon, and Derrick, 2020). The increase in N-gain for the two indicators received the most significant value, with the high category. There were only two alternatives in the PS group at the solution planning stage, so the fluency and originality skills needed to be higher. Searching for a lot and variety of information trains students' inference and literacy skills to be increasingly honed. In addition, the activities of the lecturers in the learning process support this achievement. These activities include mentoring and mentoring students working individually and in groups in working on SW, evaluating the results of problem-solving, and providing feedback and input, especially in determining alternative solutions and visualizing verbal answers in pictures. This makes the skills to think continue to grow to be more perfect.

Related to the idea evaluation stage, students must choose and decide on the best alternative solutions with various logical considerations and correct arguments. This activity will increase student flexibility and detail. The effectiveness of the evaluation skills of students in the MBCPS group was higher because, at this stage, it was carried out in a multi-representational manner. In contrast, in the PS group, it was not. Answers are multi-represented visually (images) (Table 1) as linkages to alternative solutions that require high intellect and creativity. According to Ainsworth, Prain, and Tytler (2011), drawing activities can increase engagement to communicate, explore, and justify understanding of science. Drawing precision provides an opportunity to exchange and clarify ideas. People prefer image stimuli to written words (Sweet, 2021). Various studies related to multirepresentation have been used in various materials. Multirepresentation effectively increases understanding of scientific concepts (Carolan, Prain, and Waldrip, 2008) and solves scientific problems (Zuhri et al., 2023). Various scientific concepts, such as electric fields, chemical concepts (Ferreira and Lawrie, 2019; Olaleye, 2012); work-energy concepts (Suhandi and Wibowo, 2012), solving Newton's law problems (Rizky, Tomo, Haratua, 2014), physics cognitive skills (Widianingtiyas, Siswoyo, and Bakri, 2015).

Visual answers could have been more optimal for students, with low N-gain in the PM group and moderate in the MBCPS group. This happens because drawing requires understanding and connecting material or scientific concepts (Waldrip, Prain, and Carolan, 2006), requires skill in drawing, and requires time to search for information by surfing the internet.

Studies with various learning models integrated with multi-representation can improve creative thinking skills, critical thinking skills, and learning achievement. Problem-based learning with a multi-representational approach increases learning achievement in the medium category with a gain of 0.44 (Sari et al., 2015), development of problem-based multirepresentation worksheets increases problem-solving skills reaching 85% (Maharani, Prihandono, Lesmono, 2015), inquiry learning guided by multirepresentation increases the mastery of scientific concepts (Rizal, 2014). Multi-representation-based modules improve representational abilities with an N-gain value of 0.75 in the high category (Setyandaru, Wahyuni, and Putra, 2017). Multi-representation-based Directed Activities Related to Texts (DARTS) worksheets can improve the critical thinking skills of prospective chemistry teachers (Imaduddin and Haryana, 2019). Multi-representational learning approaches and students' motivation towards physics learning outcomes (Doyan, Taufik, and Anjani, 2021).

The effectiveness of the learning model in CPCBM and PS on creative thinking skills is in the medium category, with an N-gain value between 0.4 – 0.8. This is almost the same as other studies that apply learning models. Teaching science using the Ethno-SETSaR approach scores higher scores for the creative thinking skills teachers (Winarto et al., 2022), with project-based learning (Khoiri, Ristanto and Kurniawan, 2023) and STEM-based scientific learning (Astawan et al., 2023).

Multirepresentation-based modules can improve multirepresentational abilities at high criteria with an N-gain value of 0.75 (Setyandaru et al., 2017). Several applications of the learning model did not show any difference between the experimental group and the control group. Learning with simulations and written case studies (Blakeslee, 2020), explicit textual reading between high and low levels critical thinking students (Heidari, 2020). The reasons for the N-gain that have not been maximized include 1) the time to apply the learning model is not long, 2) the implementation of research that coincides with the lecture period while students have to attend lectures and work on assignments from the courses taken, 3) The material discussed is something that new to students, so it takes time to learn and understand.

Conclusions

The Multirepresentation Based of Creaitve Problem-Solving learning model in balanced nutrition is creative learning carried out in groups to solve problems and find more and original solutions verbally, visually and mathematically. The implementation of the MBCPS Learning model in balanced nutrition can effectively improve creative thinking skills and critical thinking skills with N-gains of 0.67 (medium category) and 0.72 (high category). The CPSBM learning model differs significantly (p = 0.000) from the Problem-Solving learning model (comparison group). The implication of this research is that the CPSBM learning model is a model that can activate students and lecturers in learning, can be applied to improve higher-order thinking skills. To increase the effectiveness of learning, it is recommended to 1) increase the duration of time and frequency of CPSBM learning, by conducting group discussions outside class meeting hours, presentations are carried out effectively and efficiently, 2) expand the nutritional material taught (nutritional components, nutritional problems, nutrient metabolism) and oth-er scientific fields that have the same characteristics.

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Conflict of interests

The authors declare no conflict of interest.

Author Contributions

Literature review, data collection, statistical analysis, manuscript drafting, SF; Analysis of results and manuscript editing, language editing, EC, RSI, and SH. All authors read and approved the final manuscript.

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Appendix 1.

Examples of CPSBM problems in balanced nutrition on food diversity

Problem: Consumption of vegetables and fruits

Andi is a student who doesn't like to eat vegetables and fruits as his main food, so Andi has difficulty defecating. How many servings of vegetables and fruits are consumed daily? What is the function of vegetables and fruits in metabolism and how to increase the consumption of vegetables and fruits to be liked?

Identify the problem

Andi does not eat vegetables and often has difficulty defecating.

1. How many servings of vegetables and fruits should be consumed every day
2. What is the function of vegetables and fruits in the process of metabolism?
3. How to increase the consumption of vegetables and fruits to be liked?

Ide generation

Portions of vegetables and fruits consumed every day

1) Based on the contents of my plate, the portion of vegetables at each meal is 1/3 part vegetable, and 1/6 part fruit. If 3 main meals a day means 1 plate of vegetables and 1/2 plate of fruit / day (Ministry Ministry of Health of the Republic of Indonesia, 2014).
2) Consumption of vegetables and fruits for a healthy life amounts to 400 g per person per day, consisting of 250 g of vegetables and 150 g of fruit. A 250 g vegetable is equivalent to 2 1/2 servings or 2 1/2 cups of vegetables after cooking and draining. 150 g fruit is equivalent to 3 medium ambonese bananas or 1 1/2 pieces of medium papaya or 3 medium oranges) (Ministry Ministry of Health of the Republic of Indonesia, 2014).
3) Vegetable consumption 21/2 cup/day, with details: a) Dark green vegetables (broccoli, spinach, kale, mustard, watercress) 11/2 cup/week, red and orange vegetables (carrots, tomatoes, yellow pumpkin) 51/2 cups/week, c) legumes (peanuts, green beans, soybeans, lentils) 11/2 cup/week, d) starchy vegetables (corn, potatoes) 0 5 cups/week, other vegetables (bean sprouts, bamboo shoots, beets, asparagus, eggplant, cucumbers, letus, mushrooms, okra) 4 cups/week. Fruit consumed 2 cups/day (Sizer and Whitney, 2020)

The functions of vegetables and fruits in metabolic processes include:

1) Contains vitamins, minerals that act as antioxidants or antidotes to bad compounds in the body;
2) Contains high fiber so as to reduce the risk of difficult bowel movements (defecation / constipation) and obesity;
3) Maintain normal blood pressure, sugar levels and blood cholesterol.

Various ways to increase the consumption of vegetables and fruits to be liked by children

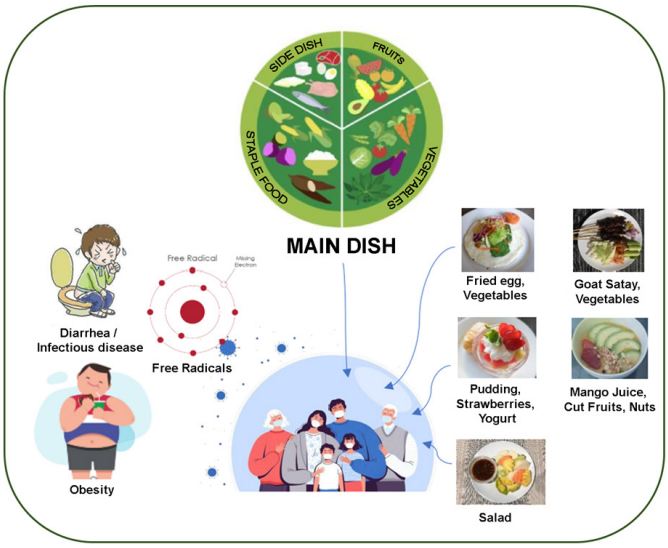
1) Include all types of vegetables in meals and snacks; Good fresh, frozen, and canned vegetables (choose low-fat and low-sodium types).
2) Store cut raw vegetables in the refrigerator, such as carrots, cucumbers, celery sticks for snacks.
3) Make or buy ready-to-eat salads. Choose vegetables that are dark green (broccoli, spinach), red or orange (tomatoes, pumpkin, carrots).
4) Try a new vegetable once every month. Read some cookbooks to get ideas.
5) Choosing whole or cut fruit more often than fruit juice.
6) Store a variety of fresh, frozen, canned low-sugar, and dried fruit to choose from as a snack or to use in cereals, yogurt, salads, or desserts.
7) Add toppings to snacks with various pieces of fruit (strawberries, berries, oranges).
8) Mix a smoothie from bananas with fruit juice or yogurt.
9) Add fruit juice with canned fruit.

Idea Evaluation

1) Verbal:

The portion of vegetables at each main meal is 1/3 part vegetable and 1/6 part fruit. Vegetables and fruits function as free radical protectors and prevent difficult bowel movements and obesity. How to increase vegetable consumption by including all types of vegetables in meals and snacks/snacks and making cut vegetables and fruits as snacks.

2) Visual



Source : private collection and freepik.com

Solution Validation

1) The contents of my plate are slogans that regulate the balanced nutrition diet of the Indonesian Ministry of Health, which is easy to understand and apply in everyday life. One-third of vegetables and one-third of fruits at each meal can meet nutritional needs, especially vitamins, minerals and fiber.
2) High vitamin and mineral content in vegetables and fruits can function as antioxidants. Anti-oxidants are compounds that protect other compounds from damaging reactions involving oxygen by itself reacting with oxygen (anti means “against”; oxy means “oxygen”). Oxidation is a potentially damaging effect on normal cell chemistry involving oxygen. By consuming anti-oxidants means protected from normal cell damage, increasing blood flow through the brain so as to help mental health sharper (Sizer and Whitney, 2020).
3) Water-insoluble fiber helps provide a feeling of fullness and helps encourage healthy bowel movements thus aiding weight loss and lowering the risk of diverticulosis, hemorrhoids, and appendicitis. Water-soluble fiber is able to bind bile and reduce the absorption of fat and cholesterol so as to promote normal blood cholesterol concentrations and reduce the risk of heart and artery disease, modulate blood glucose concentrations (reduce the risk of diabetes), bind and remove carcinogens so as to prevent colon cancer, rectal cancer and maintenance of healthy bowel function (reduce the risk of bowel disease) (Fathonah et al., 2020; Sizer and Whitney, 2020)
4) Mixing vegetables and fruits into meals and snacks or using vegetables and fruits as snacks will reduce or disguise the less desirable flavors and flavors and give new flavors and flavors.