Journal of Turkish Science Education, 2023, *20*(4), 669-694.
DOI no: 10.36681/tused.2023.038

Effects of multirepresentation-based creative problem-solving learning model on students' critical thinking and diet nutritional quality

Siti Fathonah[1], Edy Cahyono[2,*], Retno Sri Iswari[3], Sri Haryani[4], Sarwi Sarwi[5], Noer Hayati Lestari[6], Sri Kadarwati[7]

[1] *Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-9738-0665*
[2]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, edkim@mail.unnes.ac.id, ORCID ID: 0000-0001-7225-3291*
[3]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0003-1917-8717*
[4]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-7699-326X*
[5]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0001-8772-2062*
[6]*Faculty of Engineering, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-6751-1302*
[7]*Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Indonesia, ORCID ID: 0000-0002-4530-1996*

**The Research Article is a part of a doctoral dissertation*

ABSTRACT

This research investigated how the multirepresentation-based creative problem-solving (MBCPS) learning model could enhance students' critical thinking skills in relation to the Nutritional Quality of Diet. The research subjects were 72 students of the Culinary Education study program in Nutrition Science, consisting of an experimental group of 36 students with MBCPS and 36 students forming a control group using conventional problem solving. The MBCPS model consists of four stages, namely problem identification, idea generation, evaluation, and validation. The students' critical thinking skill was measured using a multiple-choice test of balanced nutrition. The Nutritional Quality of Diet is calculated from the average level of nutritional adequacy. Data analysis involved techniques using N-gain and t test. The achievement of student activities in the four stages of learning before and after the implementation of the MBCPS model experienced an increase from 52% to 68 % ($p < 0.00$). There was no difference in the critical thinking skills scores obtained by the experimental and the control groups before implementing the model ($p=0.45$). After implementing the CPSBM model, the critical thinking skills scores achieved by the experimental and control groups were 71% and 68%, which was significantly different ($p = 0.00$). An application of the model resulted for an increase of the critical thinking skills and the nutritional quality of diet got an N-gain of 0.47 and 0.28. The MBCPS model has prospects for development in a wider branch of knowledge in the scope of University Health Education.

RESEARCH ARTICLE

ARTICLE INFORMATION
Received:
11.03.2022
Accepted:
09.10.2023

KEYWORDS:
Multirepresentation, creative problem solving, critical thinking skills, balanced nutrition.

To cite this article: Fathonah, S., Cahyono, E., Iswari, R.S., Haryani, S., Sarwi, S., Lestari, N.H., & Kadarwati, S. (2023). Effects of multirepresentation-based creative problem-solving learning model on students' critical thinking and diet nutritional quality. *Journal of Turkish Science Education, 20*(4), 669-694.

Introduction

The object of the science learning process is procedural scientific work. Science involves factual, conceptual, and procedural knowledge, as well as metacognition (Wisudawati et al., 2015). Effective science teaching and learning through the application of cognitive psychology within a systematic instructional framework can help to motivate students (Meagher et al., 2018), a systematic instructional framework based on balanced learning (Sackes et al., 2020). Factual knowledge in the science context can relate to daily nutritional behavior. It could cover the concept of balanced nutrition, health, and food quality (Hardinsyah, 2017). Balanced nutrition is the arrangement of daily food that contains nutrients of the required types and amounts. The four pillars of balanced nutrition include: 1) consuming a variety of foods, 2) getting used to clean living behaviors, 3) doing physical activity, and 4) monitoring the body weight regularly to maintain the normal weight (Ministry of Health of the Republic of Indonesia, 2014).

A nutritional status is also applied for students at university. However, the nutritional status of students has been shown to vary. The prevalence of underweight and overweight was high. The World Health Organization (WHO) (2021) reported that 39% of adults were overweight and 13% were obese. A higher percentage was found for teens (Development Initiatives, 2018). At the villages in Central Java, Indonesia, a 68.8% of women of 35-49 years old were overweight (Lowe et al., 2021), meanwhile in Equador, the obesity level was of 44.2% (Hajri et al., 2021). The research has reported that the students at the Faculty of Engineering, Universitas Negeri Semarang with underweight, normal and overweight status were 23.5%, 64.2%, and 9.2%, respectively (Fathonah et al., 2018). Two years later, at the same location but different students, but the number of students with overweight drastically increased to 22.0% while those with underweight was almost unchanged (21.9%) (Fathonah et al., 2020). The improvement of the students' nutritional status was extremely important, e.g., through a learning process covering the concepts of balanced nutrition in "nutrition science" course. Educating children, teens, and adults on nutrition and healthy eating practices could create a healthy food environment.

Various learning models have been used in the learning process related to nutrition and health, such as interprofessional intervention (educating two professions together) (Asprey 2016), active learning (Santos et al., 2020). E-learning has been trialled for medical students in China (Luo et al., 2017) and teachers in Greece (Katsagoni et al., 2019), animated videos in Latinos (Calderon et al., 2014), and online health information (Aydin et al., 2015; Smith, et al., 2019).

The learning process that could support the students' activity in collaboratively, exploring creative problem solving from various solutions offered could be in accordance with the characteristics of the concepts of nutrition and health. The creative problem-solving model involves a collective effort by students to solve problems (Kim, et al., 2019) and find more original solutions (Hooijdonk, et al., 2020). This model could promote the students' higher-order thinking skills (Skeriene, et al., 2020) including creative, critical, logical, reflective, and metacognitive thinking skills.

The students' critical thinking skills in selecting dietary and food to maintain the good nutritional status through a creative problem-solving learning was covered in this study. This thinking skill is one of the must-mastered thinking skills by the students in this century, in addition to three other skills, i.e., creative, communication and collaboration skills (National Education Association, 2019). This was due to the occupational requirements for job applicants set by the employers that the critical and problem-solving thinking skills were the main requirements, not the science competence alone (Kyllonen, 2012). As various perspectives on problems were involved in the critical thinking skills (Dekker, 2020), integrating the creative problem-solving learning explicitly in the learning process was extremely important to improve the students' critical thinking skills. The

four steps in the creative problem-solving learning model, namely identification of problems, generating ideas, evaluating ideas, and validating solutions could be modified and adjusted to have more meaningful learning process and to promote the students' creativity (Nazzal, et al. 2020). The third step of the creative problem-solving model could be integrated with the multirepresentation approach to offer various forms of representation on the same certain concept to communicate the meaning of science (Nielsen et al., 2022), and develop literacy (Nielsen & Yeo, 2022). The CPS model is an educational model for collective creative endeavors or thought processes used by groups to solve problems. This model is a continuous process of using divergent and convergent thinking together at each stage, which is not segmented but interrelated and cyclical (Kim et al., 2019). Many modern models of CPS, such as the Geneplore model, have two main phases, namely generation and exploration. In the generation phase mental representations of possible solutions are collected. The exploration phase of possible solutions is explored until the best one is selected (Finke et al., 1996).

A four stage CPS model has been applied in the engineering (Cropley, 2015; Nazzal, et al., 2020; Next Generation Science Standards Lead States, 2013), and mathematics subjects with the changing of the stage of creating ideas into brainstorming (Pepkin, 2000). Pepkin model has been applied to the students and was proven to affect higher-order thinking skills and was higher than that of the conventional models (Adila et al., 2020). This study used a CPS model with the four syntaxes above. The stage of idea evaluation was expanded by multirepresentation. Multirepresentation learning is able to improve mastery of science concepts (Hubber et al., 2018, Gillies et al., 2020), scientific literacy (Prain, 2019), modeling dimension (Parent et al., 2017), and digital multimodal (Andersen et al., 2018). Multirepresentation-based worksheets were able to cultivate critical thinking skills (Abdurrahman et al., 2019). Multirepresentation-based inquiry learning was reported to effectively train the critical thinking skills in physics of high school students (Amanati, 2020). The chemistry teachers need to apply the multirepresentation to improve the students' understanding of chemistry concepts (Li & Arshad, 2014). The representation of concept of balanced nutrition in learning has been conveyed verbally, visually, and mathematically. The model developed by research is called Multirepresentation-Based Creative Problem Solving (MBCPS). The components of the learning models include syntaxes, social systems, reaction principles, supporting systems, and instructional and accompaniment impacts (Joyce et al., 2015). The syntax that has been developed in research is the CPS syntax with a factor of creative thinking skills and combined with multirepresentations.

This multirepresentation-based creative problem-solving (MBCPS) learning model could be considered as a promising collective creative way used by groups of students to solve problems by presenting the same concept in different forms. This study used the MBCPS learning model to improve students' critical thinking skills in relation to planning and implementing proper diets. MBCPS has developed critical thinking skills. Critical thinking skills are performed through activities, namely thinking solutions referring to problems, thinking deeply, thinking focused, and taking the best solution. This research objectives to analyze the learning activity of the concepts of balanced nutrition, and to analyze its effectiveness in improving the students' critical thinking skills in relation to the nutritional quality of diet. Hence, two questions have guided the current research: (i) How to analyze the learning activity of the concepts of balanced nutrition? and (ii) how to analyze its effectiveness in improving the students' critical thinking skills in relation to the nutritional quality of diet?

Methods

The Subjects of the Research

This research is investigation the effect of the MBCPS learning model on students understanding of the concepts of balanced nutrition. A purposive sampling method was used to select the subjects of the research. The subjects of the research were the students taking the course in two

separated classes with 36 students in each class. The MBCPS model was applied to one class of the subjects (experiment group), while another was using conventional problem solving (control group). In the MBCPS model, it is equipped with a textbook compiled by researchers. The textbook was prepared based on the Regulation of the Ministry of Health of the Republic of Indonesia No. 41 concerning the guidelines of balanced nutrition which contains four pillars (for control group), which were modified. The four pillars of balanced nutrition equipped with MBCPS model syntax examples, nutrition literacy and the latest research results from reputable scientific journals were explained.

The Learning Process of Multirepresentation-Based Creative Problem Solving

Table 1

The Syntax of MBCPS Learning Model has been Developed Consisting of Four Modified Stages of CPS in The Nutrition Science Lecture on The Topic of Balanced Nutrition

The phase of model	Learning activity indicator(s)
Problem identification	1) Observing and careful reading the concepts of balanced nutrition that were difficult to understand, 2) Carefully reads the problematic concept of balanced nutrition,
Idea Generation	1) Discovery of various kinds of ideas/alternative solutions according to the theory, 2) Finding various appropriate balanced nutrition problem solving techniques,
Idea Evaluation	Sequence of idea evaluation activities: 1) Determining the specific, measurable, and best solution design, 2) Presenting clear, easy to understand, and correct verbal solutions according to problem identifications, 3) Presenting visual/image solutions that contain the correct concept, communicative display, and interested readers, by searching the website to obtain quality images which are the best solutions, for example obesity, 4) Presenting mathematical solutions as a coherent way to give students opportunities to complete tasks or problems, for example calculating IMT and determining normal weight.
Solution validation	1) Applying the best solution design, 2) Comparing the solution design against the standard values or sources (if any in the literature), 3) Re-examine the best solution for the problems based on the correct concepts.

The learning activities observed was in line with the CPS syntax as reported by Nazzal et al. (2020) which included (1) problem identification, (2) idea generation, (3) idea evaluation, and (4) solution validation. At the evaluation stage, the idea was spelled out in three representations of answers. The three representations of the answer are verbally, visually, and mathematically. Table 1 lists the modified syntax of the MBCPS learning model which previously reported by Nazzal et al. (2020). The students and lecturer activities as the source of data at each stage in the syntax were displayed. The experimental activity began with the lecturer's explanation of the research and learning objectives of MBCPS. The activities carried out by students on each pillar of balanced nutrition were 1) studying the material of each pillar of balanced nutrition, 2) studying problems according to the pillars, 3) working on problems with MBCPS in groups with the stages of problem identification, idea generation, evaluation of ideas with multirepresentation, and 4) validation of solutions, 5) listening to

material explanations, 6) presenting the results of problems in class, 7) problem-solving class discussion with MBCPS, and 8) fixing the problem solutions. The activities carried out by the lecturer were 1) explaining each pillar with Zoom application, with various examples of problem solving with the MBCPS model, 2) accompanying and guiding students both works individually and in groups, 3) observing discussion and presentation activities and 4) evaluating the results of problem solving with MBCPS and providing feedback. The support system for implementing the MBCPS learning model for balanced nutrition were 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 contains 4 videos containing 4 pillars of balanced nutrition; 3) The textbook on balanced nutrition with the MBCPS model with the title "Balanced Nutrition Literacy in Science Learning" with an ISBN of 978-623-02-3790-4 (Fathonah et al., 2022), 4) Research instruments include critical thinking skills, and food nutrition quality, and 5) Other learning resources related to balanced nutrition materials in the form of e-books, textbooks, and national and international journals.

The learning outcomes included 1) mastering the concept of balanced nutrition in overcoming nutritional problems, 2) being able to solve the problems of each pillar of balanced nutrition critically and multirepresentation, and 3) being able to improve the quality of food nutrition. The instructional impact of MBCPS learning was that students master the concept of balanced nutrition. The impact of accompaniment is to improve 1) critical thinking ability, and and 2) the quality of food nutrition. The learning environment required by the learning model were 1) information technology such as laptops, tablets, iPads, and smart phones (Kaup et al., 2020); 2) using online platforms such as Zoom (Fuady et al., 2021); 3) Smooth and powerful internet connectivity (Naji et al., 2020); and 4) Universitas Negeri Semarang has a quality information technology team (Kaup et al., 2020). The students' activities during the learning process were observed and analyzed. The learning process explained that student activities in following the four stages of the MBCPS learning model. The written test with a closed-questions mode and the measurement of the students' Nutritional Quality of Diet using a food recall form were done before and after the learning activities.

Multirepresentation in the Science Learning

Multirepresentation is a variety of ways or forms of presenting an idea or concept. In science learning, the use of multirepresentation can facilitate the understanding of concepts because it supports various learning styles of students, so that competencies are easily realized in the learning process. In the learning process, students are able to produce explanations of science concepts, exhibit high-order reasoning, and interesting representations in communicating meaning (Nielson & Yeo, 2022). The results of research on pre-service science teachers showed parallel patterns, quality improvement, and the use of multirepresentations are interrelated. Students use, produce, and reflect on the level of representation that is part of the involvement of coherent argument-based laboratory activities (Yaman, 2020). Another research, in pre-service teachers on the knowledge of representations of physical and chemical changes focused on the development of cognitive structures. The use of multirepresentation makes it easier for students to master the concepts of physical and chemical changes effectively. The instructive findings have clearly addressed the difficulties teachers have experienced about particle and symbolic representations of physical and chemical changes (Derman & Ebezener, 2020). The MBCPS learning model is a development of the CPS model that has been successful in significantly uncovering critical thinking skills, which contribute to the quality of student food quality in health education.

The stages of multirepresentation in MBCPS balanced nutrition learning are as follows.

1. Students have written down the answers verbally correctly, in the order according to the identification of the problem.
2. The lecturer explains how to find various images related to the key concepts of the verbal answer, by searching/googling from the appropriate internet. Applications or web sites that create these various images include google.com (select image), freepik.com. For example, the nutritional status

of a person is depicted with a picture of a person with various body mass index (BMI) sizes accompanied by a formula for calculating BMI; risk of obesity. By looking for images of obese people equipped with the location of potentially diseased organs.
3. Students search and discuss with the group the drawing of key concepts and determine the most appropriate one.
4. The image is equipped with a brief caption. The image of the key concept is connected with an arrow to explain its interrelationships, so that a clear concept map is built.
5. Representation is opletically used for mathematical concepts, such as the BMI formula, calculating normal weight.

Data Analysis

The Learning Process of Multirepresentation-Based Creative Problem Solving

Four problems related to balanced nutrition in accordance with on the model of the multirepresentation-based creative problem-solving learning were developed and examined by three examiners with a minimum score of 0 if the students did not provide any answer and a maximum score of 3 if the students provided a correct and complete answer, as is listed in the assessment rubric of Appendix 1. An example of MBCPS problems with balanced nutrition in the weight monitoring pillar is presented in Appendix 2. Each question involved 11 indicators and four pillars balanced nutrition. Therefore, the minimum score was 0 and the maximum was 132 (4 problems x 11 indicators x 3 score) (Table 1). The average value was calculated using Equation (1). The achievement score was calculated from the division of the achieved score by the maximum score. This score was used to determine the students' achievement criteria as listed in Table 2. Meanwhile, the achievement criteria of the multirepresentation-based creative problem-solving learning activities and gain factor criteria are presented in Table 3 and Table 4, respectively.

Table 2

Component and Score the Multirepresentation-Based Creative Problem-Solving Learning Activities

Stages of MBCPS	Number of indicators	Maximum score
Problem identification	2	24
Ideas generation	2	24
Idea evaluation	4	48
Validation of solutions	3	36
MBCPS learning achievement	11	132

$$Mean = \frac{Total\ score\ of\ all\ respondent}{Number\ of\ responden} \quad (1)$$

Example Mean of problem identification = = $\frac{529}{36} = 14.7$

$$Achievement\ of\ maximum\ score = \frac{Mean}{Score\ maximum}\ x\ 100\ \% \quad (2)$$

$$Exampel\ chievement\ of\ maximum\ score = \frac{14.7}{24}\ x\ 100\ \% = 61.2\ \%$$

Table 3

The Achievement Criteria of the Multirepresentation-Based Creative Problem-Solving Learning Activities

Achievement criteria	Percentage
Very low	0.0 – 20.0
Low	20.1 – 40,0
Fair	41.1 – 60,0
High	60.1 – 80.0
Very high	80.1 - 100.0

$$N - gain = \frac{<Score_{post}> - <Score_{pre}>}{<Score_{max}> - <Score_{pre}>} \quad (3)$$

The effectiveness of implementing the MBCPS learning model between the experimental group and the control group is measured by N-gain or <g> (Fadaei, 2019). The N-gain value for each respondent is calculated using Equation (3), while the N-gain value for MBCPS learning is the average of all respondents. The <g>, <Spre> and <Spost> in Equation (3) were designated as N-gain or gain factor, average score pre-test of Nutrition and Health concepts (%), and average score post-test on Nutrition and Health concepts (%), respectively.

Table 4

Gain Factor Criteria <g>

Gain factor <g>	Description
<g> ≥ 0.7	High
0.7 > <g> ≥ 0.3	Fair
<g> < 0.3	Low

The Students' Critical Thinking Skills

The data collected in this research included 1) observation results of students' learning activities on the MBCPS learning process, 2) written test results on the concepts of balanced nutrition (critical thinking skills applied to balanced nutrition) as is shown in Appendix 3, and 3) results of food recall form on the intake filled out by the students. The students' critical thinking skill was measured using a multiple-choice test instrument on the concept of balanced nutrition, according to the stages of the thinking process to solve the problems correctly. The critical thinking indicators used in this study are analysis, inference, evaluation, and decision making. application, evaluation, analysis and synthesis (Nasution et al., 2023). The students' answers were scored based on the critical thinking steps using a reference scale of 1 - 4.

Diet Nutritional Quality

The Nutritional Quality of Diet is measured quantitatively with the food recall form for seven days as published by the Ministry of Health of the Republic of Indonesia. The nutritional value of each food ingredient consumed by the students was calculated based on the reference list of food ingredient composition and compared with the nutritional adequacy referring to the 2019 Recommended Dietary Allowances (RDA). The percentage of the Nutrition Adequacy Level (NAL) was calculated using equation (Lim & Choue, 2013) and the categories are listed in Table 5. The students' Nutritional Quality of Diet was then calculated based on the value of the nutrition adequacy level using equation (Kementerian Kesehatan Republik Indonesia, 2019).

Table 5

Categories of Nutritional Adequacy Levels (NAL)

Category	Percentage NAL
Deficit	<70% RDA
Lack	70% - 80% RDA
Medium	80% - 99% RDA
Good	>100 AKG

Note. Source: Kementerian Kesehatan Republik Indonesia, 2019

$$Nutrition\ Adequacy\ Level = \frac{Amount\ Nutrition\ of\ Cosumption}{Recommended\ Dietary\ Allowances}\ x\ 100\% \quad (4)$$

$$Nutritional\ Quality\ of\ Diet = \frac{Amount\ of\ Nutritional\ Adequacy\ Level}{Amount\ of\ item\ nutrition} \quad (5)$$

All data collected was analyzed descriptively to determine the effectiveness of the MBCPS learning model during the teaching and learning process, as well as its effect on students' critical thinking abilities and the Nutritional Quality of Diet. Differences in students' critical thinking abilities and Nutritional Quality of Diet before and after the learning process were analyzed using the paired sample t test (Bonamente, 2017) and the experimental and control groups were also analyzed using N-gain (Fadaei, 2019).

Findings

The Multirepresentation-Based Creative Problem-Solving Learning Process

A slight improvement in the MBCPS learning for the "experiment group" was observed with a maximum score before and after the implementation of the MBCPS learning model of 40 % and 53 %, respectively. The N-gain value due to the implementation of the MBCPS learning model for the "experiment group" was 0.21 with a low category. The detail learning achievement after the implementation syntax of the MBCPS learning model for the experiment group is presented in Table 6.

Table 6

The Detailed Results of The Learning Activities and Its Achievement in The Implementation Syntax of the MBCPS Learning Model for the "Experiment Group"

Syntax of MBCPS learning model	Before MBCPS learning implementation				After MBCPS learning implementation				Sig p < 0.05
	Mean	SD	Achievement of maximum score		Mean	SD	Achievement of maximum score		
			Score	Category			Score	Category	
Problem identification	14.7	2.4	61	fair	18.7	2.1	78	high	0.00
Ideas generation	10.7	3.8	45	fair	11.9	3.4	50	fair	0.02
Idea evaluation	10.9	1.5	24	low	19.7	2.1	44	fair	0.00
Validation of solutions	15.4	1.9	43	fair	17.8	0.8	49	fair	0.00
MBCPS learning achievement	51.6	7.3	40	low	68.1	6.6	53	fair	0.00

The implementation of the MBCPS learning model was carried out for the "balanced nutrition" concepts. Four syntax in the creative problem solving were involved during the learning activities, namely problem identification, idea generation, idea evaluation, and validation of solution. The increase in problem identification scores in the high category from 61% before to 78% after implementing the MBCPS learning model, was significant at $p < 0.05$. The problems given in the student worksheets are explicitly problems that students must solve so that the problem identification stage is relatively easy for students to complete. Meanwhile, the idea generation stage only achieved a-half of the maximum score with no significant change in the learning achievement observed. More efforts to find other solutions towards provided problems through literature review from e-books and published research papers.

Moreover, the learning achievement of the idea evaluation to conclude the best alternative answers after the implementation of the MBCPS learning significantly increased by two-fold increment from 24% before to 44% after the learning. Meanwhile, an insignificant increase in the learning achievement from 43 % to 49% was observed for the validation toward solutions. This suggested the low and negligible change in the students' creativity. The students found it difficult in stating the complete verbal answers and illustrating the verbal to visual answers. Therefore, the students were required to improve the literature study and their concept understanding.

The Students' Critical Thinking Skills

The students' critical thinking skills in this study were measured based on the stages of the thinking process, namely the skill to argue, the skill to make inferences, the skill to evaluate, and the skill to generate the best solution for the problems. The example of critical thinking skills is listed in Appendix 3. The students' critical thinking skills were determined before and after the learning process for each group involved in the research. The results showed that there was no significant difference between the students' critical thinking skills of the "experiment" and the "control" groups before the implementation of particular learning process. Even, the indicators of inference skill and decision-making skill showed the same average value.

Overall, the students' critical thinking skills of the "experiment" group and the "control" group after the learning process was significantly different, with p value of 0.00* (Table 7). It indicated that the implementation of the MBCPS learning model could enhance the students' critical thinking skills. Among the indicators of the critical thinking skills, the indicators of analytical skill and evaluation skill showed a significant difference as indicated by the p value of the two indicators of 0.01 and 0.00, respectively. However, only a slight difference was observed for the indicators of the inference skill and the decision-making skill with a p value of 0.82 and 0.11, respectively.

Table 7

Results of the Assessment and the Differential Test of The Students' Critical Thinking Skill

Indicators of Critical Thinking	Before the learning process			After the learning process		
	Experiment Group	Control Group	p in t-test	Experiment Group	Control Group	p in t-test
Analytical Skill	6.4	15.8	0.21	18.3	17.4	0.01*
Inference Skill	17.3	17.3	0.86	18.2	18.1	0.82
Evaluation Skill	14.7	14.6	0.75	17.6	15.7	0.00*
Decision Making Skill	14.8	14.8	0.96	17.0	16.4	0.11
Critical Thinking Skill	63.2	62.3	0.45	71.1	67.6	0.00*

Note.* Significant difference before and after learning

The Students' Diet Nutritional Quality

The students' Nutritional Quality of Diet consumption includes the adequacy level of energy, carbohydrate, protein and fat. Before the implementation of the MBCPS learning model, the students' Nutritional Quality of Diet consumption measured in this study was quite concerning, as indicated by the value of the nutritional adequacy level mostly (above 50%) in the deficit category (nutrition adequacy level below 70%). These conditions were observed in all indicators of the adequacy of energy, carbohydrates, protein, fat, and Nutritional Quality of Diet (as is shown in Table 8).

After the implementation of MBCPS and conventional learning model for the "experiment" and "control" group, respectively, the overall Nutritional Quality of Diet, energy, protein, and fat for both groups has improved towards an adequate nutrition level. However, the carbohydrate adequacy level for both the "experiment" and "control" groups was totally in a deficit level. Furthermore, the protein adequacy level was the only average nutritional quality that was in the medium category (80-99%). The four other nutritional adequacy aspects, i.e., energy, carbohydrates, fats and the overall Nutritional Quality of Diet were below 70% on average. Moreover, the nutritional quality of carbohydrates was only about 45%. By comparing the results of the students' nutritional quality of before-after learning state, there was no significant difference of that before and after learning, except for the fat adequacy level with a p-value of 0.01 (as is shown in Figure 1). The Nutritional Quality of Diet presented in Figure 1 clearly shows the level of the students' nutritional adequacy. It indicated that the highest level of protein adequacy and the lowest level of carbohydrate adequacy had been achieved. Overall, the nutritional quality of diet was still at deficit level (59.2–73.6%).

Table 8

Description of the Students' Nutrition Quality of Diet of the "Experiment" and "Control" Groups Before and After the Implementation of the Learning Model

Types of Nutritional Quality	Before/after learning	Group	Deficit		Lack		Medium		Good	
			n	%	n	%	n	%	n	%
Energy Adequacy Level	Before	Experiment	2	88.9	1	2.8	3	8.3	-	-
		Control	31	86.1	2	5.6	3	8.3	-	-
	After	Experiment	29	80.6	3	8.3	4	11.1	-	-
		Control	18	50.0	12	33.3	5	13.9	1	2.8
Carbohydrate Adequacy Level	Before	Experiment	34	94.4	2	5.6	-	-	-	-
		Control	34	94.4	1	2.8	1	2.8	-	-
	After	Experiment	36	100.0	-	-	-	-	-	-
		Control	36	100.0	-	-	-	-	-	-
Protein Adequacy Level	Before	Experiment	29	80.6	3	8.3	4	11.1	-	-
		Control	28	77.8	5	13.9	2	5.6	1	2.8
	After	Experiment	7	19.4	7	19.4	10	27.8	12	33.3
		Control	5	13.9	8	22.2	10	27.8	13	36.1
Fat Adequacy Level	Before	Experiment	25	69.4	5	13.9	6	16.7	-	-
		Control	20	55.6	7	19.4	5	13.9	4	11.1
	After	Experiment	24	66.7	2	5.6	6	16.7	4	11.1
		Control	13	36.1	6	16.7	10	27.8	7	19.4
Nutrition Quality of Food	Before	Experiment	29	80.6	3	8.3	4	11.1	-	-
		Control	28	77.8	5	13.9	2	5.6	1	2.8
	After	Experiment	20	55.6	8	22.2	6	16.7	2	5.6
		Control	11	30.6	12	33.3	12	33.3	1	2.8

Table 9

The Effectiveness Level of the Multirepresentation-Based Creative Problem-Solving Learning

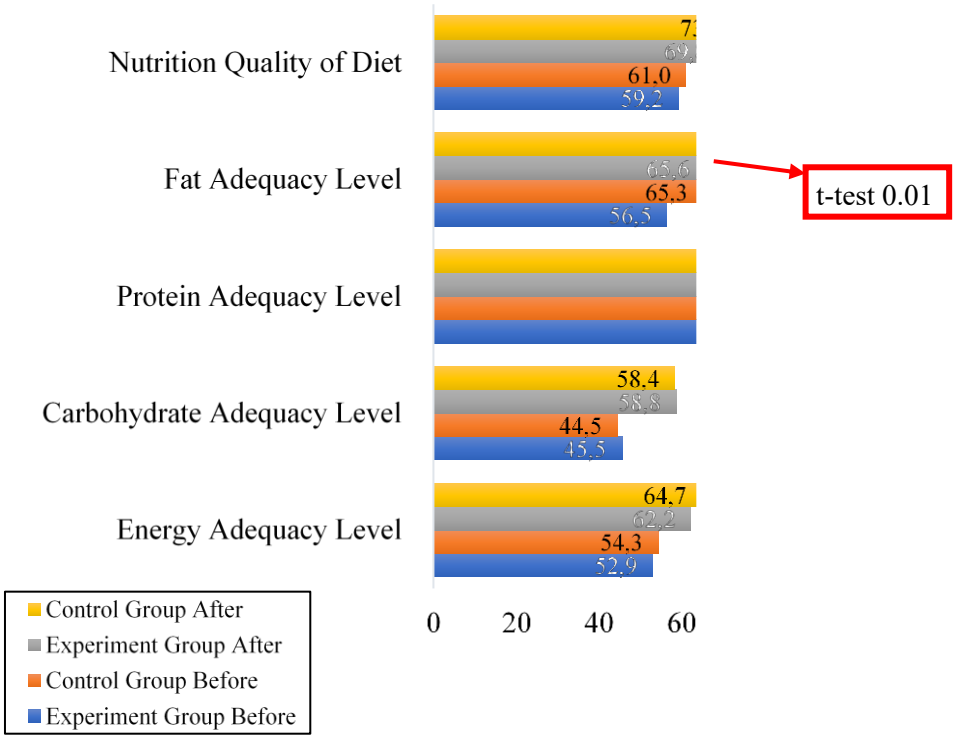
Measured parameter	N-gain		p in t-test
	Experimental group	Control group	
Critical Thinking Skill	0.47 (medium)	0.31 (medium)	0.00*
Nutrition Quality of Diet	0.28 (low)	0.36 (medium)	0.03*

Note. *Significant difference before and after learning

The learning outcomes showed that the N-gain of the "experiment" group was higher in the critical thinking skills with moderate criteria compared to that of the "control" group (as is shown Table 9). This suggested that the MBCSP model was quite effective in enhancing the students' critical thinking skills, and significant at $p < 0.05$. In contrast, the Nutritional Quality of Diet of the students in the "experiment" group achieved a low-level N-gain or low effectiveness, while those in the "control" group obtained the N-gain with a medium category or a moderate effectiveness level, but significant at $p < 0.05$.

Figure 1

Average Score of the Students' Nutritional Quality of Diet before and after the Implementation of Conventional and MBCPS Learning Models for the "Experiment" and "Control" Groups



Discussion

The implementation of the MBCPS learning model during the nutrition science course was carried out in this study. It was shown that the students' critical thinking skills have improved to the moderate level, except for the Nutritional Quality of Diet for the students in the "experiment" group. This indicated the significance of the implementation of the MBCPS learning model in enhancing the students' critical thinking skills. Moreover, the improvement of the critical thinking skills and

nutritional quality of diet for the students in the "experiment" was higher in comparison with those for the students in the "control" group, indicated by a very significant *t*-test value (both variables with a p value of 0.00).

During the implementation of the MBCPS learning model for the "experiment" group, several typical learning activities were employed, i.e., 1) working in groups to share knowledge and experiences (Mayseless et al., 2019; Sophonhiranraka et al., 2015), 2) generating beneficial solutions for all group members and between groups, 3) deciding the best solution for all groups, 4) developing creative thinking skills (Cetinkaya, 2014), 5) developing critical thinking skills (Kim et al., 2019; Nazzal et al., 2020), and 6) improving creativity (Cetinkaya, 2014; Nazzal et al., 2020; Phaksunchai et al., 2014). During the MBCPS learning process, the students worked in peer groups with different skill levels to articulate the concept understanding and solve the higher-level problems (Mahalingam et al., 2017). This type of learning could enhance the students' self-reflective learning and engagement through providing feedback. Furthermore, the students enjoyed the challenging learning experiences (Strohfeldt et al., 2015).

The students' ability in generating ideas and validating solutions did not significantly change after the implementation of MBCPS learning model in the "nutrition science" course. It was in the low category. It suggested that the students' ability to solve each problem has been done correctly, although not all of them are correct, with various alternative solutions. The students' skill to locate and find the solutions to problems from various available literature (e.g., modules, textbooks, and scientific journals) has not developed maximally. Moreover, the students could not find the most correct solutions for the problem in the stage of validation of solutions. Validation of solution activities in the problem-solving process could be a good challenge. In addition to problem solving, the results of these activities could help bringing positive impacts and feedback (Sennewald et.al., 2021). In advanced, collaborative activities involving knowledge and experience sharing between students in groups were highly required (Grott, 2019, O'Neil, 2014). Specifically, the divergent way of thinking to create widely various thoughts was necessary for generating ideas (Phaksunchai et al., 2014).

Related to the idea evaluation stage, where students are required to choose and decide on the best alternative solution with various logical considerations and correct arguments. This activity can increase flexibility and detail, and student evaluation abilities. An improvement in the students' ability to evaluate ideas by 16.6 points (before and after the implementation of the MBCPS learning model from low to moderate category) was observed. The effectiveness of the CPSBM group was higher because this stage was carried out in a multi-representation manner, and not in the control group. Answering multiple visual representations (images), in the form of linking alternative solutions, requires high thinking and creativity. According to Ainsworth et al. (2011) drawing activities can increase engagement, to communicate, explore and justify understanding in science. The precision of the images provides an opportunity to exchange and clarify ideas. Besides, people prefer image stimulation to written words (Sweet, 2021). Various research related to multirepresentations has been used in various materials. Multiple representations have been proven to be effective in increasing understanding of scientific concepts (Carolan *et al*., 2008). Various scientific concepts, such as chemical concepts (Ferreira & Lawrie, 2019; Olaleye, 2012), work-energy concepts (Suhandi & Wibowo, 2012), solving Newton's law problems (Rizky *et al.,* 2014), cognitive abilities physics (Widianingtiyas, 2015).

The lowest stage of multiple representation is visualizing verbal answers into visuals. Students have not been able to immediately find pictures that match the verbal answer key concepts, connected by arrows to explain the relationship. Some students visualize using leaflets that are available on the internet so that it is not suitable for verbal answers and a clear concept map has not been formed. This happens because visualizing verbal answers requires high imagination, the ability to explore and is something new for students. This is in line with previous research which states that students focus more on visualizations of other people. Creating visualizations is an integral part of scientific thinking and improving understanding (Ainsworth et al., 2011; Ferreira et al., 2019). Visualization in class needs to be thoroughly integrated into the curriculum (da Silva et al., 2022).

Research that supports the importance of multiple representations in learning includes developing knowledge about scientific concepts and processes and having the potential for effective learning (Waldrip et al., 2006), increasing scientific literacy (Prain, 2019), increasing scientific literacy (Gillies et al., 2020; Waldrip et al., 2006), and quality learning (Hubber et al., 2018). Therefore, mastery of multiple representations needs to be maintained and even developed further in the learning process by extending the duration of the learning process.

After the MBCPS learning process, there was an increase in critical and different thinking skills in the experimental group and the control group, which was supported by indicators of analytical ability and evaluation ability. This happened because analysis and evaluation skills were the most important abilities in critical thinking that had been taught since learning. Various studies with various learning models show the same results, namely increasing critical thinking skills, including the Discovery Learning Model (Nurrohmi et al., 2017), the Wiki Learning Project (Crist et al., 2017), the Teaching Factory Based on Troubleshooting learning model (Maksum et al., 2022), and Scratch-assisted Wave teaching materials (Negoro et al., 2023). Critical thinking skills are very necessary in the learning process and dealing with various problems that arise. This is in accordance with research (de la Sienra, 2020) which states that critical thinking skills have been considered an important skill for future success and encouraging innovation.

The students' critical thinking skills investigated in this study showed an insignificant difference in all critical thinking indicators, either in groups (pre-test to post-test) or between groups (simulation versus written case studies) (Blakeslee, 2020). Moreover, no significant difference between the students with high and low critical thinking in the explicit textual reading. However, the students' ability in reading implied texts and item-based scripts in both "experiment" and "control" groups differed significantly (Heidari, 2020).

Nutritional adequacy, including energy, carbohydrates, protein and fat, increased after learning in both the experimental and control groups. However, the level of energy and carbohydrate adequacy is still in the deficit category (> 70%). This shows that students do not have a good diet, they still lack macronutrients. This result is the same as Indonesian national data on adolescents and adults which shows energy and carbohydrate deficits, even protein and fat (Rahmawati et al., 2016). If this lack of energy is not immediately corrected, it can result in malnutrition. Energy adequacy is very important because energy intake is the main predictor of micronutrient adequacy (Gibson, 2007). Energy adequacy is very important to support health and life (Sizer et al., 2020). The new recommendations issued by WHO regarding carbohydrate intake for everyone aged 2 years and over should come from whole grains, vegetables, fruit and nuts. WHO recommends adults consume at least 400 grams of vegetables and fruit and 25 grams of natural dietary fiber per day (WHO, 2023). Conditions are better at the level of protein adequacy in the medium category, around 91-93%. Adequate protein nutrition will support students to study better. Proteins play a role in behavioral and neurocognitive development (Garcia et al., 2018, Kadosh et al., 2021).

The nutritional quality of food is indicated by the average nutritional adequacy in the moderate category (70% in the control group and 74% in the experimental group), but is close to a deficit. The same results occurred for German students in the same moderate level category as measured by the Healthy Eating Index (HEI-NVS) (Nossler et al., 2022). Therefore, it is recommended for students to increase food consumption towards balanced nutrition. Student responses after implementing the CPSBM learning and conventional learning that had been given regarding problems in balanced nutrition encouraged students to pay more attention to eating patterns, both in terms of types of food and portions. Students understand what foods are good to consume and what foods to reduce, but still pay attention to nutritional adequacy.

Conclusion and Implications

The achievement of student activities in the four stages of learning before and after the implementation model increased from 52% to 68%. Learning achievement in evaluating ideas to

conclude the best alternative solution after implementing MBCPS learning increased significantly by two times and they were actively involved in learning. The effectiveness rate of the MBCPS learning model is still relatively reasonable with an achievement of 53%; whereas in the experimental group students improved critical thinking skills ($p < 0.05$) and Nutritional Quality of Diet ($p < 0.05$). MBCPS learning on balanced nutrition material is effective and able to improve critical thinking skills and Nutritional Quality of Diet with N-gains of 0.47 (moderate level) and 0.28 (low level), respectively. From the research analysis, it was found that the development of students' critical thinking skills, on the topic of "balanced nutrition" was sufficient. Research findings that students' critical thinking skills can assist students in choosing food and eating patterns to maintain a good daily diet and increase the level of nutritional adequacy to normal.

Through learning MBCPS, students can obtain good health and well-being with normal nutritional adequacy status, both from excess and deficiency levels of nutritional adequacy. Improving the quality and effectiveness of the developed model needs to be applied to more sample questions and extending the learning process from 5 weeks to a minimum of 7 weeks so that student activities are more detailed and can be assessed more accurately. The MBCPS model has prospects for development in a wider branch of knowledge in the scope of University Health Education.

References

Abdurrahman, A., Setyaningsih, C. A., & Jalmo, T. (2019). Implementating multiple representation-based worksheet to develop critical thinking skills. *Journal of Turkish Science Education*, *16*(1), 138-155. DOI: 10.12973/tused.10271a

Adila, R., Hartono, Y., Indaryanti, Scristia, & Yusup, M. (2020). The effect of creative problem-solving models on students' higher level thinking skills in linear programming. *Journal of Physics: Conference Series*, *1480,* 012047. https://doi.o10.1088/1742-6596/1480/1/012047

Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to learn in science. *Science, 33*(6046), 1096–1097. https://doi.org/10.1126/science.1204153

Amanati, A. (2020). The effectiveness of learning instrument of multiple representations-based inquiry model to train critical thinking skills in physics lesson. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *9*(1), 1772–1776. https://doi.org/10.26740/jpps.v9n1.p1772-1776

Andersen, M.F., & Munksby, N. (2018). Didactical design principles to apply when introducing student-generated digital multimodal representations in the science classroom. *Designs for Learning*, *10*, 112-122. https://doi.org/10.16993/DFL.100

Asprey, D. (2016). A model for educational efficiencies. In P.A. Cuff, (Ed.), *Envisioning the future of health professional education* (pp. 26-29). The National Academies Press. https://www.ncbi.nlm.nih.gov/books/NBK362409/pdf/Bookshelf_NBK362409.pdf

Aydin, G.O., Kaya, N., & Turan, N. (2015). The role of health literacy in access to online health information. *Procedia - Social and Behavioral Sciences*, *195*, 1683-1687. https://doi.org/10.1016/j.sbspro.2015.06.252

Blakeslee, J.R. (2020). Effects of high-fidelity simulation on the critical thinking skills of baccalaureate nursing students: A causal-comparative research study. *Nurse Education Today*, *92*, 104494. https://doi.org/10.1016/j.nedt.2020.104494

Bonamente, M. (2017). *Statistics and analysis of scientific data* (2nd Ed.). Springer Nature. https://doi.org/10.1007/978-1-4614-7984-0

Calderon, J.L., Shaheen, M., Hays, R.D., Fleming, E.S., Norris, K.C., & Baker, R.S. (2014). Improving diabetes health literacy by animation. *Diabetes Educ*ation, *40*(3), 361-372. https://doi.org/10.1177/0145721714527518

Cetinkaya, C. (2014). The effect of gifted students' creative problem-solving program on creative thinking. *Procedia - Social and Behavioral Sciences*, *116*, 3722-3726. https://doi.org/10.1016/j.sbspro.2014.01.830

Crist, C.C., Duncan, SE., & Bianchi, LM. (2017). Incorporation of cross-disciplinary teaching and a wiki research project to engage undergraduate students to develop information literacy, critical thinking, and communication skills. *Research in Food Science Education*, *16*, 81-91. https://doi.org/10.1111/1541-4329.12111

Cropley, D. H. (2015). *Creativity in engineering: novel solutions to complex problems*. Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-800225-4.00002-1

de la Sienra, E. (2020). Holistic thinking and the worldviews-based learning framework. In W. Filho, A.M., Azul, L., Brandli, P.G., Özuyar, & T., Wall (Eds.). *Quality education. Encyclopedia of the UN sustainable development goals* (pp 407–419). Springer, Cham. https://doi.org/10.1007/978-3-319-95870-5_6

da Silva, A.J.P., & Arroio, A. (2022). The role of time in the use of visualization in chemical education: pre-service teacher practices, *Journal of Turkish Science Education, 19*(3), 758-772. https://doi.org/10.36681/tused.2022.148

Dekker, T.J. (2020). Teaching critical thinking through engagement with multiplicity. *Thinking Skills and Creativity*, *37*, 100701. https://doi.org/10.1016/j.tsc.2020.100701

Derman, A. & Ebenezer, J. (2020) The effect of multiple representations of physical and chemical changes on the development of primary pre-service teachers' cognitive structures. *Res Sci Educ, 50*, 1575–1601. https://doi.org/10.1007/s11165-018-9744-5

Development Initiatives. (2018). *Global nutrition report: shining a light to spur action on nutrition.* https://reliefweb.int/report/world/2018-global-nutrition-report-shining-light-spur-action-nutrition?gad_source=1&gclid.

Fadaei, A.S. (2019). Comparing two results: hake gain and dellow gain, to analyze force concept inventory data in active learning process. *US-China Education Review A*, *9*(1), 31-39. https://doi.org/10.17265/2161-623X/2019.01.003

Fathonah, S. (2018). The influence of activities and nutrition status to university students' achievements. *AIP Conference Proceedings 1941*(1), 020008-1- 020008-6. https://doi.org/10.1063/1.5028066

Fathonah, S., Sarwi, S., Wusqo, I.U., Cahyono, E., Hanifah, N., & Agustin, L.R. (2020). Pengaruh literasi kesehatan dan literasi gizi terhadap status gizi mahasiswa UNNES. *Prosiding Seminar Pasca sarjana UNNES 2020*, *3*(1), 1063-1070. Pascasarjana UNNES. https://proceeding.unnes.ac.id/snpasca/article/view/1321/838

Fathonah, S., Cahyono, E., Iswari, R.S., Haryani, S., Sarwi, S., & Lestari, N.H. (2022). Balance nutrition literature teaching materials in creative problem solving based multirepresentation learning model. In Kusumastuti, A et al. (Eds.): VEIC 2022, *Advances in Social Science, Education and Humanities Research,* 697, 123-131. https://doi.org/10.2991/978-2-494069-47-3_17

Finke, R. A., Ward, T. B., & Smith, S. M. (1996). *Creative cognition: Theory, research, and applications.* MIT Press.

Ferreira, J.E., & Lawrie, G. (2019). Profiling the combinations of multiple representations used in large-class teaching: pathways to inclusive practices. *Chemistry Education Research and Practice*, *20*, 902-923. https://doi.org/10.1039/c9rp00001a

Fuady, I., Sutarjo, M. A. S., & Ernawati, E. (2021). Analysis of students' perceptions of online learning media during the covid-19 pandemic (study of e-learning media: zoom, google meet, google classroom, and LMS). *Randwick International of Social Science Journal*, *2*(1), 51–56. https://doi.org/10.47175/rissj.v2i1.177

García, M.R.M., Ortega, J.A.I., Sobaler, L.A.M., & Ortega, R.M. (2018). Estrategias nutricionales que mejoran la función cognitiva [Nutrition strategies that improve cognitive function]. *Nutr Hosp.* 7(35), 16-19. Spanish. doi: 10.20960/nh.2281

Gibson, S.A. (2007). Dietary sugars intake and micronutrient adequacy: a systematic review of the evidence. *Nutrition Research Reviews, 20*(02), 121-131. doi: 10.1017/S0954422407797846

Gillies, R., & Rafter, M. (2020). Using visual, embodied, and language representations to teach the 5E instructional model of inquiry science. *Teaching and Teacher Education*, *87*, 102951.

Grott, R. (2019). Problem-solving. In A. Shay (Ed.). *Assistive technology service delivery: a practical guide for disability and employment professionals* (pp. 127-144). Academic Press. https://doi.org/10.1016/B978-0-12-812979-1.00009-6

Hardinsyah. (2017). Sejarah dan masa depan ilmu gizi. In Pakar Gizi Indonesia. *Ilmu Gizi: Teori dan Aplikasinya* (pp. 1-11). EGC.

Hajri, T., Angamarca-Armijos V., & Caceres L. (2021). Prevalence of stunting and obesity in Ecuador: a systematic review. *Public Health Nutr*, *24*(8), 2259-2272. doi: 10.1017/S1368980020002049

Heidari, K. (2020). Critical thinking and EFL learners' performance on textually explicit, textually implicit, and script-based reading items. *Thinking Skills and Creativity*, 37, 100703. https://doi.org/10.1016/j.tsc.2020.100703

Hooijdonk, M.V., Mainhard, T., Kroesbergen, E.H., & Tartwijk, J. (2020). Creative problem solving in primary education: exploring the role of fact finding, problem finding, and solution finding across tasks. *Thinking Skills and Creativity*, *37*, 100665. https://doi.org/10.1016/j.tsc.2020.100665

Hubber, P., Tytler, R., & Chittleborough, G. (2018). Representation construction: a guided inquiry approach for science education. In R. Jorgensen & K. Larkin (Eds.). *STEM Education in the Junior Secondary School* (pp. 57-87). Springer.

Joyce, B., Weil, M., & Calhoun, E. (2015). *Models of Teaching (*9 th ed.*)*. Pearson Education.

Kadosh, C. K., Muhardi, L., Parikh, P., Basso, M., Jan Mohamed, H.J., Prawitasari, T., Samuel, F., Ma, G., & Geurts, J.M. (2021). Nutritional support of neurodevelopment and cognitive function in infants and young children-an update and novel insights. *Nutrients*, *13*(1), 199. https://doi.org/10.3390/nu13010199

Kaup, S., Jain, R., Shivalli, S., Pandey, S., & Kaup, S. (2020). Sustaining academics during COVID-19 pandemic: the role of online teaching-learning. *Indian Journal of Ophthalmology*, *68*(6), 1220–1221. https://doi.org/10.4103/ijo.IJO_1241_20

Katsagoni, C.N., Apostolou, A., Georgoulis, M., Psarra, G., Bathrellou, E., Filippou, C., Panagiotakos, D.B., & Sidossis, L.S. (2019). Schoolteachers' nutrition knowledge, beliefs, and attitudes before and after an e-learning program. *Journal of Nutrition Education and Behavior*, *51* (9), 1088-1098. https://doi.org/10.1016/j.jneb.2019.07.001

Kementerian Kesehatan Republik Indonesia. (2019). *Peraturan Menteri Kesehatan Republik Indonesia Nomor 28 tahun 2019 tentang angka kecukupan gizi yang dianjurkan untuk masyarakat Indonesia.* Kementerian Kesehatan Republik Indonesia. http://hukor.kemkes.go.id/uploads/produk_hukum/PMK_No__28_Th_2019_ttg_Angka_Kecukupan_Gizi_Yang_Dianjurkan_Untuk_Masyarakat_Indonesia.pdf.

Kim, S., Choe, I., & Kaufman, J.C. (2019). The development and evaluation of the effect of creative problem-solving program on young children's creativity and character. *Thinking Skills and Creativity*, *33*, 100590. https://doi.org/10.1016/j.tsc.2019.100590

Kyllonen, P.C. (2012). Measurement of 21st century skills within the common core state standards. In *Invitational Research Symposium on Technology Enhanced Assessments*. https://www.ets.org/Media/Research/pdf/session5-kyllonen-paper-tea2012.pdf

Li, W.S.S., & Arshad, M.Y. 2014. Application of multiple representation levels in redox reactions among tenth grade chemistry teachers. *Journal of Turkish Science Education, 11*(3), 35-52. doi: 10.12973/tused.10117a

Lim, H., & Choue, R. 2013. Diet quality and cerebral infarction: South Korean aspects. In V. Preedy, L.A. Hunter, & V. Patel (Eds.). *Diet quality, nutrition and health* (pp. 29-45). Humana Press.

Lowe, C, Kelly M, Sarma H, Richardson A, Kurscheid J.M., Laksono B, Amaral S, Stewart D, & Gray D.J. (2021). The double burden of malnutrition and dietary patterns in rural Central Java, Indonesia. *Lancet Reg Health West Pac*, *15*(14), 100205. doi: 10.1016/j.lanwpc.2021.100205

Luo, L., Cheng, X., Wang, S., Zhang, J., Zhu, W., Yang, J., & Liu, P. (2017). Blended learning with Moodle in medical statistics: an assessment of knowledge, attitudes and practices relating to e-learning. *BMC Medical Educ*ation, *17*(170), 1-8. https://doi.org/10.1186/s12909-017-1009-x

Mahalingam, M., & Fasella, E. (2017). Effective use of technology for asynchronous learning to elevate students' knowledge and problem-solving ability. In *Unplugging the classroom: Teaching with technologies to promote students' lifelong Learning* (pp. 149-158). Elsevier Ltd.

Maksum, H., Yuvenda, D., & Purwanto, W. (2022). Improvement of metacognitive and critical thinking skills through development of a 'teaching factory based on troubleshooting' (tefa-t) model in automotive vocational learning. *Journal of Turkish Science Education, 19*(3), 1015-1036. https://doi.org/10.36681/tused.2022.161

Mayseless, N., Hawthorne, G. & Reiss, A.L. (2019). Real-life creative problem solving in teams: fNIRS based hyperscanning study. *NeuroImage, 203*, 116161. https://doi.org/10.1016/j.neuroimage.2019.116161

Meagher, B.J., Carvalho, P.F., Goldstone, R.L., & Nosofsky, R.M. (2018). Correction to: organized simultaneous displays facilitate learning of complex natural science categories. *Psychonomic Bulletin & Review, 25*(4), 1563. https://doi.org/10.3758/s13423-018-1509-7

Ministry of Health of the Republic of Indonesia. (2014). Food-based dietary guidelines - Indonesia. https://www.fao.org/nutrition/education/food-dietary-guidelines/regions/countries/indonesia/en/

Naji, K.K., Xiangyun Du, X., Tarlochan, F., Ebead, U., Hasan, M.A., & Al-Ali, A.K. (2020). Engineering students' readiness to transition to emergency online learning in response to COVID-19: Case of Qatar. *EURASIA Journal of Mathematics, Science and Technology Education*, *16*(10), em1886. https://doi.org/10.29333/ejmste/8474

Nasution, N., Irawati, A.M.M.H., Sapta, S.M, & Balgis. (2023). Relationship between critical thinking skills, creative thinking skills, and learning achievement in biology course: a study of education level and gender differences, *Journal of Turkish Science Education, 20*(1), 66-83. https://doi.org/10.36681/tused.2023.005

National Education Association. (2019). Preparing 21st century students for a global society: an educator's guide to the "four Cs". https://dl.icdst.org/pdfs/files3/0d3e72e9b873e0ef2ed780bf53a347b4.pdf

Nazzal, L.J., & Kaufman, J.C. (2020). The relationship of the quality of creative problems solving stages to overall creativity in engineering students. *Thinking Skills and Creativity*, *38,* 100734. https://doi.org/10.1016/j.tsc.2020.100734

NGSS Lead States. (2013). *Next Generation Science Standards: for states, by states*. The National Academies Press.

Negoro, R.A., Rusilowati, A., & Aji, M.P. (2023). Scratch-assisted waves teaching materials: ict literacy and students' critical thinking skills, *Journal of Turkish Science Education*, *20* (1), 189-210. https://doi.org/10.36681/tused.2023.011

Nielsen, W. & Yeo, J. (2022). Introduction to the special issue: multimodal meaning-making in science. *Res Sci Educ, 52*, 751–754. https://doi.org/10.1007/s11165-022-10051-z

Nielsen, W., Turney, A., Georgiou, H. & Jones, P. (2022). Meaning making with multiple representations: a case study of a preservice teacher creating a digital explanation. *Res Sci Educ, 52,* 871–890. https://doi.org/10.1007/s11165-021-10038-2

Nossler, C., Schneider, M., Schweter, A. et al. (2023). Dietary intake and physical activity of German university students. *J Public Health*, *31*, 1735–1745 https://doi.org/10.1007/s10389-022-01729-9

Nurrohmi, Y., Utaya, S., & Utomo, D.H. (2017). Pengaruh model pembelajaran discovery learning terhadap kemampuan berpikir kritis mahasiswa. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *2*(10), 1308-1314. doi:10.17977/jptpp.v2i10.10062

Olaleye, B. (2012). *Enhancing teachers' knowledge for using multiple representations in teaching chemistry in Nigerian senior secondary schools* [theses]. Edith Cowan University. https://ro.ecu.edu.au/theses/494

O'Neil, H.F., Chuang. S.H., & Baker, E.L. (2010). Computer-based collaborative problem solving. In D. Ifenthaler, P. Pirnay-Dummer, & N. M. Seel (Eds.). *Computer-based diagnostics and systematic analysis of knowledge* (pp. 261-279). Springer- Verlag.

Parent, C., Spaccapietra, S., & Zimányi, E. (2008). Modeling and multiple perceptions. Springer science buisiness media. doi:10.1007/978-0-387-35973-1_805

Pepkin, K. L. (2000). *Creative problem solving in Math*. https://uh.edu/honors/Programs-Minors/honors-and-the-schools/houston-teachers-institute/curriculum-units/pdfs/2000/articulating-the-creative-experience/pepkin-00-creativity.pdf

Phaksunchai, M., Kaemkate, W., & Wongwanich, S. (2014). Research and development of a training package for developing creative problem solving of undergraduate students. *Procedia - Social and Behavioral Sciences, 116*, 4824-4828. https://doi.org/10.1016/j.sbspro.2014.01.1032

Prain, V. (2019). Future research in learning with, through and from scientific representations. In V. Prain & B. Hand (Eds.). *Theorizing the future of science education research* (pp 151–168). Springer, Cham. https://doi.org/10.1007/978-3-030-24013-4_10

Rahmawati, R., Hardinsyah, H., & Roosita, K. (2015). Pengembangan indeks gizi seimbang untuk menilai kualitas gizi konsumsi pangan remaja (13-15 tahun) di Indonesia. *Jurnal MKMI*, *11*(3), 160-167. https://journal.unhas.ac.id/index.php/mkmi/article/view/525

Rizky, G., Tomo, D., Haratua, T.M.S. (2014). Kemampuan multirepresentasi siswa SMA dalam menyelesaikan soal-soal hukum newton. *Khatulistiwa*, *3*(8), 1-10. https://jurnal.untan.ac.id/index.php/jpdpb/article/view/6733

Sackes, M., Trundle, K.C. & Shaheen, M. (2020). The Effect of balanced learning curriculum on young children's learning of science. *Early Childhood Education Journal*, *48*, 305–312. https://doi.org/10.1007/s10643-019-00985-x

Santos, A.G.C., Fagundes, A., Barbosa, K.B.F., & Barreto, N.S. (2020). Students' perspective on active learning in nutrition education. *Journal of Nutrition Education and Behaviour*, *52*(4), 415-420. https://doi.org/10.1016/j.jneb.2019.09.012

Sennewald, C.A., & Baillie, C. (2020). Problem solving. In *Effective security management*. (7th Ed.). Butterworth-Heinemann. https://www.elsevier.com/books/effective-security-management/sennewald/978-0-12-814794-8

Sizer, F. S., & Whitney, E. (2020). *Nutrition: concepts & controversies*. (15th Ed.). Cengage Learning, Inc. https://www.cengage.com/c/nutrition-concepts-and-controversies-15e-sizer/9781337906371PF/

Skeriene S., & Juceviciene, P. (2020). Problem solving through values: A challenge for thinking and capskill development. *Thinking Skills and Creativity*, *37*, 1-11. https://doi.org/10.1016/j.tsc.2020.100694

Smith, B., & Magnani J.W. (2019). New technologies, new disparities: The intersection of electronic health and digital health literacy. *International Journal of Cardiology*, *12*(92), 280-282. https://doi.org/10.1016/j.ijcard.2019.05.066

Sophonhiranraka, S., Suwannatthachoteb, P., & Ngudgratokec, S. (2015). Factors affecting creative problem solving in the blended learning environment: a review of the literature. *Procedia-Social and Behavioral Sciences*, *174*, 2130–2136. https://doi.org/10.1016/j.sbspro.2015.02.012

Strohfeldt, K., & Khutoryanskaya, O. (2015). Using problem-based learning in a chemistry practical class for pharmacy students and engaging them with feedback. *American Journal of Pharmaceutical Education*, *79*(9), 1-11. https://doi.org/10.5688/ajpe799141

Suhandi, A., & Wibowo, F. C. (2012). Pendekatan multirepresentasi dalam pembelajaran usaha-energi dan dampak terhadap pemahaman konsep mahasiswa. *Jurnal Pendidikan Fisika Indonesia*, *8*(1), 1-7; https://journal.unnes.ac.id/nju/index.php/JPFI/article/view/1988

Sweet, J. (2021). "The effect of item presentation (pictorial, verbal, and combination) on choice overload and tendency to opt-out of choice". *Honors Economics Posters*, *19*. https://digitalworks.union.edu/eco499p_2021/19

Waldrip, B., Prain, V., & Carolan, J. (2006). Learning junior secondary science through multi-modal representations. *Electronic Journal of Science Education*, *11*(1), 86-105. http://ejse.southwestern.edu/volumes/v11n1/articles/art06_waldrip.pdf

WHO. (2021). *Obesity and overweight*. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight

WHO. (2023). *Updates guidelines fats and carbohydrates*. https://www.who.int/news/item/17-07-2023-who-updates-guidelines-on-fats-and-carbohydrates

Widianingtiyas, L., Siswoyo, S., & Bakri, F. (2015). Pengaruh pendekatan multi representasi dalam pembelajaran fisika terhadap kemampuan kognitif siswa SMA. *Jurnal Penelitian & Pengembangan Pendidikan Fisika, 1*(1), 31 - 38. https://doi.org/10.21009/1.01105

Wisudawati, A.W., & Sulistyowati, E. (2015). *Metodologi pembelajaran sains*. Bumi Aksara.

Yaman, F. (2020). Pre-service science teachers' development and use of multiple levels of representation and written arguments in general chemistry laboratory courses. *Res Sci Educ, 50*, 2331–2362. https://doi.org/10.1007/s11165-018-9781-0

Appendices

Appendix 1

Assessment Rubric of the Multirepresentation-Based Creative Problem-Solving Learning Activities for Students

No Component	No Indicator	Indicator	Rubric	
			Score level	Explanation of score level
1	1	Problem recognition of balanced nutrition	3	problem recognition is correct, unambiguous (double meaning), and detailed
			2	Problem recognition is correct and unambiguous, and not detailed
			1	Problem recognition is correct, ambiguous and not detailed
			0	No answer/wrong
	2	Thorough in reading the concept of balanced nutrition	3	According to the steps completely, thoroughly, and correctly
			2	According to the steps in full, thorough and something is not right
			1	According to the steps in full, less thorough and not correct
			0	Not doing
2	1	Generating ideas	3	Conveys ideas, poses problems, unbiased/focused problems
			2	Convey ideas, pose problems, there are biases
			1	Convey ideas, don't pose problems and be biased
			0	Be passive
	2	Find troubleshooting methods.	3	Found some way, gave a revision, and correct.
			2	Found some way and correct and do not give revisions.
			1	Found some ways, some are not right.
			0	Did not find a way.
3	1	Assess/choose the best solution.	3	Compare a number of solutions, select and determine the best one.
			2	Comparing a number of solutions, choosing one solution is not the best.
			1	Choosing the solution is not the best.
			0	Choose wrong.

	2	Verbal Presentation	3	Presentation in full writing, detailed and correct explanation.
			2	Presentation in full writing, detailed explanations and some are not true.
			1	Presentation in full writing.
			0	Incomplete presentation.
	3	Visual presentation .	3	Presentation with complete pictures, detailed and correct explanations.
			2	Presentation with complete pictures, detailed explanations and some are not true
			1	Presentation with complete images.
			0	Presentation with incomplete images.
	4	Math presentation	3	Carry out procedures, write equations / representations correctly, complete components and in detail.
			2	Carry out procedures, write down equations/ representations correctly and in less detail.
			1	Implement solution procedures but are incomplete and not detailed.
			0	Not carrying out the wrong procedures and solutions.
4	1	Solution Validation	3	Carry out procedures, write equations/ representations correctly, complete components and in detail
			2	Carry out procedures, write down equations/ representations correctly and in less detail
			1	Carry out solution procedures but are incomplete and not detailed
			0	Not carrying out the wrong procedures and solutions
	2	Comparing the solution plan with the standard	3	Solution plan according to standard, rational and correct
			2	The solution plan is standard and rational and something is not right
			1	Solution plan according to standard, irrational and incorrect
			0	Solution plan is not up to standard
	3	Re-check the best solution based on the right concept	3	The best solution according to the concept, complete and correct
			2	The best solution according to the concept, complete and some are not correct
			1	The best solution according to the concept, incomplete and incorrect
			0	The best solution doesn't fit the concept

Appendix 2

Examples of MBCPS Problems with Balanced Nutrition in The Weight Monitoring Pillar

In order for balanced nutrition learning of the Multirepresentation-Based Creative Problem-Solving model to be successful, steps need to be taken before lectures.

1. Study, examine, and understand a textbook with the title "Balanced Nutritional Literacy in the Context of Science Learning". The textbook consists of 5 chapters. Chapter 1 contains nutrition, health and learning. Chapters 2 – 5 contain a description of the pillars of nutrition which in each section contains the material presented, examples of MBCPS learning, nutritional and health literacy with questions, as well as research results from national journals and related international journals that are up-to-date.
2. MBCPS learning includes four stages, namely 1) problem identification, 2) idea generation, 3) idea evaluation, verbal, visual, and mathematical answers, and 4) solution validation.
3. To work on each problem followed according to the instructions.

> Andin's mother, 25 years old, wants to have an ideal weight with a height of 161.2 cm. Mrs. Andin currently weighs 62.7 kg with a waist circumference of 78. Ms. Andin has cholesterol levels of 210, fasting blood sugar of 150 mg/dL, uric acid levels of 3.1, and glomerular filtration rate (LPG) of 88. Mrs. Andi wants to know the nutritional status and ideal weight that must be maintained. What disease risk factors do you have?

4. In the stage of identifying problems that must be done is to read, understand and analyze nutritional and health problems properly. Problem identification is done by writing down different problems and must be solved to get the best solution.

> Ibu Andin i weighs 62.7 kg with a waist circumference of 78 cm
> 1) What is Mrs. Andin's nutritional status?
> 2) What is his normal weight?
> 3) What are the risk factors experienced by Ms. Andin?

5. To get a lot of ideas, you have to read various textbooks, national journals and international journals related to problem identification. Each question in problem identification is sought for as many alternative answers as possible that are different and correct or at least get 2 or 3 alternative answers. The more alternative answers found the better the stage of idea generation. Sort the answer alternatives from the best and most likely to do.

1. Idea generation

1. How to determine nutritional status
   1) With Body Mass Index (BMI)
      BMI = weight (kg)/TB2 (m) = 62.7/1.6122 = 24.1 (normal BMI 18.5 - 25.0).
   2) Broca's Formula (Nutrition Installation of Dr. Cipto Mangunkusumo Hospital and the Indonesian Dietesian Association, 2004) :
      Normal weight = (Height (cm) – 100) - 10 %
      = (161.2 –100) – 6.1 = 61.2 – 6.1 = 55.1 kg
      Mrs. Andin's weight is 62.7 kg greater weight idel 55.1 kg.
   3) Based on Mrs. Andin's waist circumference 78 cm lower than the normal limit of 80 cm, it means that it is classified as a normal weight.

2. Normal weight
   1) Based on the BMI formula calculated minimum normal weight and maximum normal weight

$$BB_{normal\ minimal} = IMT_{normal\ minimal}\ x\ TB^2$$
$$BB_{normal\ minimal} = 18{,}5\ x\ 1{,}612^2 = 18{,}5\ x\ 2{,}598 = 48{,}1$$
$$BB_{normal\ maksimum} = IMT_{normal\ maksium}\ x\ TB^2$$
$$BB_{normal\ minimal} = 24{,}9\ x\ 1{,}612^2 = 24{,}9\ x\ 2{,}598 = 64{,}7$$

      Normal weight between 48.1 to 64.7 kg
   2) Based on Broca's formula. The normal weight of Broca's formula ± 10%. Calculation result above 55.1 kg
      Normal weight = [(Height (cm) – 100) - 10 %] ± 10 %
      = [(161.2 – 100) -6.1] ± 10 %
      = 55.1 ± 5.51
      Minimum normal weight = 55.1 – 5.51 = 49.6 kg
      Maximum normal weight = 55.1 + 5.51 = 60.6 kg
      Normal body weight is between 49.6 to 60.6 kg
   3) Based on normal body weight, Minister of Health Regulation No. 28 of 2019 concerning Recommended Nutritional Adequacy Rates for Indonesian people, 55 kg
3. The risk factors experienced by Mrs. Andin are heart disease, diabetes and kidnev disease. Uric acid levels are still in the normal

6. Based on the answers or information obtained at the stage of idea generation is analyzed in group discussions. In the group discussion are compiled alternative answers to all questions in order to make verbally correct decisions in detail, in order, and interrelated. A verbal answer is an answer that is presented in easy-to-understand sentences.

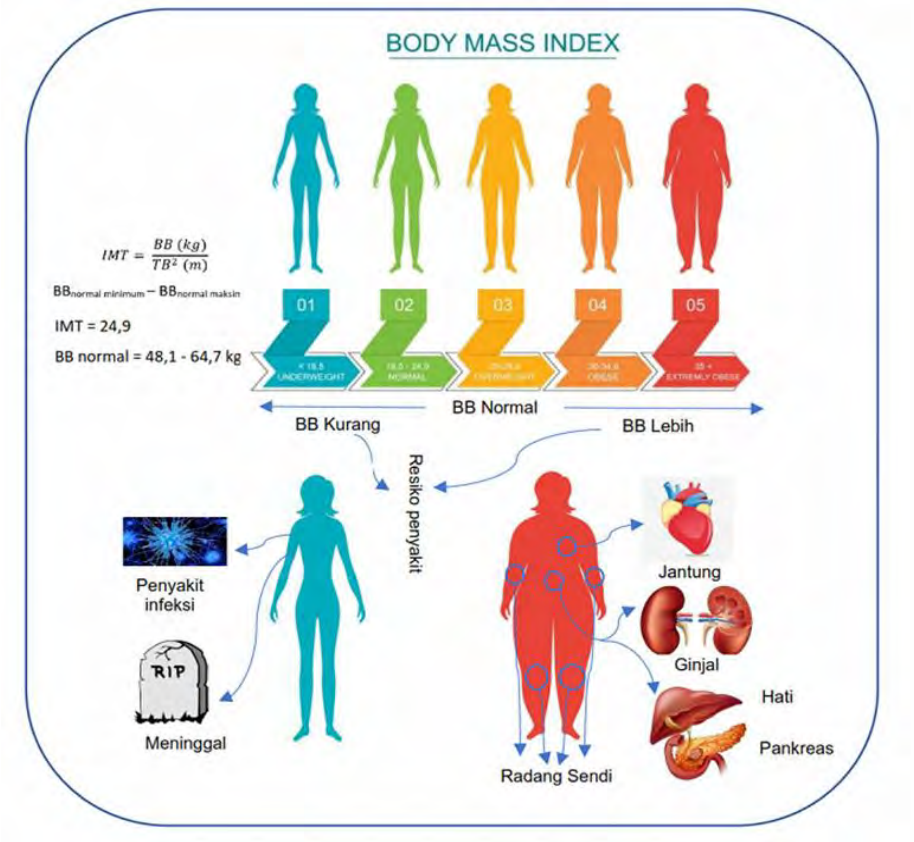
Idea Evaluation

1) **Verbal**:

The nutritional status of adults is most appropriate using the BMI indicator. BMI = weight (kg)/ Height 2 (m) = 62.7/1.6122 = 24.1 (normal BMI 18.5 - 25.0). Based on the BMI formula, the minimum normal weight can be calculated at a BMI of 18.5 and a maximum weight at a BMI of 24.9 and obtained a value of 48.1 to 64.7 kg. The risk of diseases that may be experienced is heart disease, diabetes and kidneys.

7. Based on verbal answers, you look for images or photos from various sources (textbooks, journals, leaflets) that are appropriate, and combine them with arrows that make them look interesting, and easy to understand, answers.

2) Visual



8. If there is a calculation in the verbal answer, you rewrite the formula and the calculation result in the mathematics section.

3). Mathematics

IMT = Weight (kg)/ Height2 (m) = 62.7/1.6122 = 24.1 (BMI normal 18.5 – 25.0).

Normal weight is calculated from the minimum normal weight and the maximum normal weight

$BB_{normal\ minimal} = IMT_{normal\ minimal}\ x\ TB^2$

$BB_{normal\ minimal} = 18.5\ x\ 1.612^2 = 18.5\ x\ 2.598 = 48.1$

$BB_{normal\ maksimum} = IMT_{normal\ maksium}\ x\ TB^2$

$BB_{normal\ minimal} = 24{,}9\ x\ 1{,}612^2 = 24{,}9\ x\ 2{,}598 = 64{,}7$

9. At the solution validation stage, you must conduct an analysis to find the correct reason and strong evidence for each answer in the evaluation of ideas from various sources of textbooks, journals and research results.

Validation towards Solutions

1) BMI is a simple healthy weight indicator, relatively inexpensive and easy to measure. BMI can be used as the most suitable measurement indicator to be carried out alone or in conjunction with the central adiposity indicator (Laurent et al., 2020). Based on the BMI value obtained, it can be categorized as a person's nutritional status.
2) Based on the BMI formula and the criteria, the normal weight range can be calculated by calculating the minimum normal weight and maximum normal weight. Furthermore, it can be determined what actions must be taken immediately to regulate body weight, maintain if the weight category is normal, increase weight if underweight and lose weight if overweight.
3) Based on the criteria for blood owned, the risk of the disease can be determined. Cholesterol levels affect the work of the heart. The normal limit for cholesterol levels is <200 mg/dL. Sugar levels are related to diabetes, with normal limits for fasting blood sugar > 126 mg/dL (Sulistyowati, 2017). Uric acid levels associated with arthritis with normal limits for women between 3.4 -7 (Perjan Nutrition Installation RS Dr. Cipto Mangunkusumo and the Indonesian Dietetic Association, 2004). The glomerular filtration rate (LPG) shows kidney function with a normal limit of 90 (Kresnawan, 2017)

10. All the answers in each MBCPS stage are read and re-evaluated in groups to tabulate that the work has been completed properly and correctly.

Appendix 3

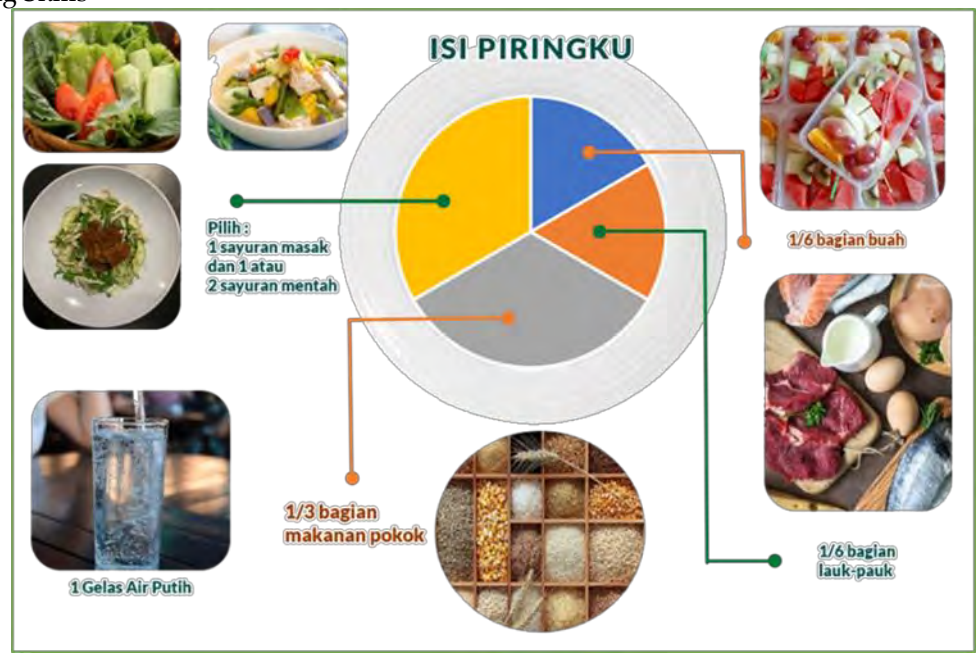
An Example of Critical Thinking Ability Instrument
Instructions: Choose the one correct answer
Analytical ability

1. To fulfill balanced nutrition, it is necessary to consume a variety of foods. The best staple foods are:
   A. Perfectly milled rice because it is white and fluffier.
   B. Brown rice that still contains high fiber and vitamin B1
   C. Polished black rice because it contains high fiber and antioxidants and complex carbohydrates
   D. Instant rice because it cooks quickly and is easy to digest
2. Fish and meat are recommended to be consumed as side dishes. The most appropriate choice decision in consuming fish compared to meat is:
   A. Fish contains perfect protein and high unsaturated fatty acids
   B. Fish contains imperfect protein but contains saturated fatty acids
   C. Beef contains perfect protein and high cholesterol
   D. Beef contains imperfect protein with high unsaturated fatty acids.

Inference Skills

3. Udin has a BMI of 30.5, has a habit of eating fried dishes without vegetables and doesn't like to exercise. Udin's risks are:
   A. more nutritional status, difficulty defecating and high blood fat
   B. normal nutritional status, low cholesterol and high blood pressure
   C. normal nutritional status, high cholesterol and difficulty defecating
   D. obesity, suffering from cardiovascular disease, and difficulty defecating
4. Diarrhea often occurs and is considered a mild disease that is considered trivial. The following are associated with the incidence of diarrhea:
   A. Food contaminated with bacteria, *Escherichia coli* type and not washing hands before eating
   B. food contaminated with a virus, the type of *Escherichia coli* and not washing hands before eating
   C. Food contaminated with bacteria, *Salmonella typhi* and dirty home environment
   D. food contaminated with viruses, *Salmonella typhi* and dirty home environment

Evaluating Skills



5. Based on my plate illustration, raw vegetables are consumed more than cooked vegetables:
   A. Raw vegetables have enzymes that are still active, are acidic and at least 3 servings a day
   B. Raw vegetables have enzymes that are still active, are alkaline and at least 2 servings a day
   C. raw vegetables have antioxidants that are still active, are acidic and a maximum of 2 servings a day
   D. Raw vegetables have inactive antioxidants, are alkaline and a maximum of 2 servings a day

6. Based on the illustration above, what is your nutritional status:
   A. You are overweight so you must consume energy at a minimum limit of basal metabolic energy and do physical exercise for at least 30 minutes/day, and do not need treatment
   B. You are overweight so you have to consume energy at the minimum limit of basal metabolic energy and do physical exercise for at least 250 minutes/week, and need treatment
   C. You are overweight so you must consume energy at a minimum energy adequacy rate and do physical exercise for at least 250 minutes/week, and need treatment
   D. You are overweight so you must consume energy at a minimum energy adequacy rate and do physical exercise for at least 30 minutes/day, and do not need treatment

Decision Making Skills

7. At home, three types of animal side dishes are provided, namely steamed milkfish, fried catfish, and beef empal and three types of vegetable side dishes, namely bacem tempeh, bacem tofu and fried tempeh. You are asked to choose one animal side dish and one vegetable side dish. Which combination of side dishes is the highest in protein and healthy (note the weight of the ingredients is the same):
   A. Peped milkfish and fried tempeh
   B. Pepes milkfish and marinated tofu.
   C. Fried catfish and fried tempeh
   D. Empal beef and bacem tofu.
8. To maintain normal body weight, do a combination of diet and physical exercise. Choose and do the best combination is:
   A. Minimum energy consumption according to basal metabolic energy and physical exercise 200 minutes/week
   B. Maximum energy consumption according to energy adequacy rate and physical exercise 200 minutes/week
   C. Maximum energy consumption according to basal metabolic energy and physical exercise 300 minutes/week
   D. Minimum energy consumption in accordance with energy adequacy figures and physical exercise of 300 minutes/week