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Enhancing the quality of future teaching practise by increasing scientific attitudes and reducing misconceptions of pre-service elementary school teachers through conceptual change model

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Enhancing the quality of future teaching practise by increasing scientific attitudes and reducing misconceptions of pre-service elementary school teachers through conceptual change model

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Abstract. This study was aimed at increasing scientific attitudes and reducing misconceptions of 39 pre-service elementary school teachers (PSESTs) at PGRI University of Yogyakarta by implementing the conceptual change model (CCM). Scientific attitudes scales (SAS) and misconception tests (MT) were administered to PSESTs. Observations and documentations were conducted to record the implementation of CCM as well as PSESTs' attitudes and behaviour. Data analysis techniques were the descriptive statistic as a quantitative analysis and descriptive qualitative as a qualitative analysis. The average scores of scientific attitudes increased from 72.8 in the initial condition to 77.1 in Cycle I, whilst the average scores of scientific attitudes increased from 77.1 in Cycle I to 81.4 in Cycle II. The overall misconception incidences reduced from 49.8% to 5.6%. The research results clearly showed that CCM increased scientific attitudes and reduced misconceptions of PSESTs'. The two objectives, the increase of scientific attitudes and reduction of misconceptions, are attempts to enhance the quality of pre-service teachers' upcoming teaching practise. Consequently, CCM is one of the choices that can be chosen by lecturers to fulfil both objectives.

1. Introduction

Concept is considered one of the contents of curricula. PSESTs enter teacher training programme with concepts acquired by them in the prior educational level and their daily lives. Unfortunately, they sometimes come to the teacher training programme bringing notions that are irrelevant with the true conceptions [1-4]. This fact is potential to presume because it is impossible for pre-service teachers to impart valid conceptions to their future students if their understandings are contaminated by flawed information (misconceptions) [1]. The issue on misconceptions was also found amongst PSESTs at PGRI University of Yogyakarta. This problem implies that reducing PSESTs' misconception should be attempted by igniting dissatisfaction with their prior conceptions.

The attempt on conflicting prior conceptions and the new conceptions is called conceptual change. The connection between prior conceptions and acquired conceptions is complex as it is influenced by individual's conceptual ecology [4]. The conceptual ecology is a form of conceptual framework, helping individuals to understand objects or phenomena [5], [6]. The conflict between prior concept and the new concept is regarded as a condition needed by PSESTs to change the prior conceptions if those are proven as wrong ideas [7], [8]. The form of cognitive conflict may vary but it is often emphasised the importance of recognising students' prior conceptions and confronting them by carrying out activities such as class discussion, experiment, and the presentation of contradictory information that may reveal the flaws in their prior conceptions [9].

The cognitive conflict models of learning were designed to accommodate the theory of conceptual change [10], [11]. The theoretical basis of the conceptual change model was developed by philosophers and science educator at Cornell University [5] and was later modified by several educational researchers [12]. Based on the CCM which was developed by Cornell University [5], there are four conditions which need to be considered: (1) subjects must realise their prior conceptions contain flaws; (2) the new conceptions can be understood by the subjects; (3) the new conceptions are acceptable and logical; and (4) the new conceptions must possess a potential for further explanation in new domains. CCM will also give PSESTs chances to (1) acquire the new concepts and replace their prior conceptions; (2) accept the new concepts alongside their prior conceptions; (3) decline the new concepts; (4) separate prior concepts and the new concepts [3]. When CCM is aimed at remembering and assimilating, the teaching practise normally consists of clarifying content presented in texts, formulating solutions to problems, demonstrating principles, supplying laboratory practises, and testing for recalling of conceptions and ability to implement knowledge to problems; whereas if teaching practise is aimed at accommodation, lectures, demonstration, and laboratory activities might also be implemented in order to ignite cognitive conflict and to trigger anomalies for the subjects [12]. A number of researches argued in their studies that CCM could be implemented to reduce and to remediate students' misconception. The findings of those researchers can be found in the reference: [7], [9], [13-25].

The effort aimed at reducing PSESTs' misconceptions will be meaningless if it is not integrated with a comprehensive attempt in building PSESTs' scientific attitudes. Scientific attitudes are a set of attitudes regarding one's perspective or specific opinion relating to object or phenomena in science [26] and not only existed in science education but extent [27]. These attitudes have distinct characteristics compared to attitudes towards sciences by which attitudes towards science are solely associated to individual's preference to science. Based on the synthesis regarding the aspects of scientific attitudes from reference [28-32], the scientific attitudes are associated with curiosity, critical thinking, inventiveness, respect for evidence, open-mindedness, perseverance, and social sensitivity. This study should be realised as efforts in enhancing the quality of future's teaching practise in the level of elementary education.

2. Methods

This study was a classroom action research (CAR) implementing 3-step activity adopted from Kemmis & McTaggart's spiral design. The steps were (1) plan, (2) act and observe, (3) reflect and revise [33]. The subjects were 39 PSESTs of A4 class at PGRI University of Yogyakarta comprising 25 females and 14 males.

The data collecting techniques were observations, questionnaires, tests, and documentations. Those techniques are (1) observation regarding the implementation of CCM; (2) questionnaires concerning scientific attitudes; (3) tests for identifying PSESTs' misconceptions; (4) documentations. PSESTs' scientific attitudes were intrinsically measured using questionnaires called scientific attitudes scale (SAS) that consisted of 25 items. Each item of SAS was based on a 4-point Likert scale. PSESTs' misconception incidence was identified using misconception tests (MT). Observation guidelines were utilised to record the implementation of CCM and PSESTs' activities during the teaching intervention. SAS and MT were administered in every meeting.

The qualitative data were obtained using documentations. The qualitative data were then described based on the observation aspects comprising CCM implementation and the description of PSESTs' behaviour and attitudes. The quantitative data were obtained from SAS and MT. The quantitative data were then analysed using quantitative analyses. The data related to PSESTs' scientific attitudes were also categorised as a part of the analysis system. The categorisation system was established in order to reveal the change of scientific attitudes and it was adopted from reference [34]. Score which is less than 69.06 is considered Low category; score which lies in range $69.06 \leq \text{Score} \leq 81.73$ is considered Fair category; score which is greater than 81.73 is considered High category.

3. Result and Discussion

3.1. Result and Discussion Concerning Initial Condition

The initial data regarding PSESTs' scientific attitudes were collected using SAS in the first meeting. All of the activities done by PSESTs were observed and documented. Individual's scientific attitudes scores were also analyzed. The number of PSEST possessing low, fair, and high scientific attitudes were 9, 28, and 2, respectively. The average scores on curiosity, critical thinking, inventiveness, respect for evidence, open-mindedness, cooperativeness, perseverance, and social sensitivity were 74.2, 70.4, 72.2, 72.2, 75.4, 73.7, 70.7, and 73.1, respectively. The overall average score on scientific attitudes was 72.8. By consulting with categorization system, all of aforementioned scores were categorized in Fair category.

3.2. Result and Discussion Concerning Cycle I

3.2.1. Plan. There were 3 meetings planned in Cycle I by which each meeting comprising one topic. The topics of the course were interpreted as follows: (1) the topic of the first meeting was the characteristics of living things; (2) the topic of the second meeting was the levels of organisation of living things; and (3) the topic of the third meeting was the human movement system.

3.2.2. Act and observe. The action done in Cycle I was the lecturer encouraged PSESTs to do brainstorming about wrong conceptions regarding the topic of the corresponding meeting. PSESTs were grouped by considering fair and homogenous distribution of characteristics such as cognitive ability, aptitude, gender, race, and learning style. A group of PSESTs who were in duty took the lecturer's role to carry out and to organize the activities of the meeting. The group prepared the presentation, paper, worksheets, as well as apparatus and materials needed for the hands-on activities. The paper containing explanations about the topic they got was then submitted to the lecturer and the collaborating lecturer for reviewing. PSESTs' prior conceptions were exposed and challenged to new information they found.

MT, in this research positioned itself as posttest, was then administered to PSESTs to measure the misconception incidence as the teaching intervention had been given. In Cycle I, the number of PSEST possessing low, fair, and high scientific attitudes were 3, 29, and 7, respectively.

One of the keys of science is objectivity. This aspect was also the only aspect of scientific attitudes that elevated from fair category to high category in Cycle I (see table 1). Respect for evidence has the highest increment amongst all of the aspects of scientific attitudes, gaining 10.6 points in Cycle I if it is compared to the initial condition. Individual's learning perspectives affect the level to which cognitive conflict happens in teaching practice based on CCM – whether he acquires the conflicting evidence or whether he enforces coping strategies to condemn the evidence [35], [36]. Moreover, subjects involve making judgements related to the truth or falsity of notions on the basis of evidence [12].

The difference of critical thinking scores between the initial condition and Cycle I was 5.4. People sometimes need to conceptualize the evidence so that it can be understandable for them. This may be caused by the vagueness and a limited number of collected evidences. The rational consideration of the evidence, the reflective thoughtfulness of new conceptions, and the justification of uncertainty conditions necessitated by scientific thinking demand critical thinking and problem-solving skill, and sometimes require a radical change of one's ways of thinking [37], [38].

Majority studies on conceptual change focus on students and those are advantageous to regard additional student-focused literature for insight into pre-service teachers' efficacy [39], [40]. Individuals decide to seek new information in order to resolve a certain situation that needs to be understood and solved. These considerations should make PSESTs aware against the probability of wrong conceptions they currently believe. The aforementioned assumptions are also parallel with the research results showing that the average of perseverance increased from 70.7 in the initial condition to 72.4 in Cycle I.

Based on the research results, PSESTs' cooperativeness increased from 73.7 in the initial condition to 78.7 in Cycle I, whereas social sensitivity increased from 73.2 in the initial condition to 75.4 in Cycle I. Although in the Basic Science 1 course is focused on equipping conceptual foundation to PSESTs, they were also required to perform their involvements in the hands-on activities in the form of experiments, observations, and demonstrations. In Every meeting starting from Cycle I, one group had a duty to organize class activities in the corresponding session. Other groups who did not on duty take role as audiences and did activities which had been organized. This scheme of teacher training is based on the consideration that science is actually a participation activity, and if the social aspects of the instruction to be fully realized, subjects must be involved to interact with others [41]. The social context of the classroom, self-efficacy and control belief of students, 'student's goals, aims, purposes, expectations and needs' are as crucial as cognitive strategies in concept learning [42]. Furthermore, reference [43] also states that group learning gives positive impacts towards concept learning, whereas Vygotsky's theories [44] underline the grandness of motivational and social factors. Prior studies that implemented CCM by considering subjects' cooperativeness were conducted by [45] and [46]. We can infer that research findings are consistent with the ground theories regarding the importance of cooperativeness and social sensitivity in science education.

The presence of conflicting information assisted subjects to reflect about their ideas to establishing explanations about events being studied, and probably subjects' reflection could ignite their curiosity [47]. The research results show that their curiosity increased from 74.2 in initial condition to 77.4 in Cycle I. This finding implies that CCM generally activated PSESTs' curiosity. Older subjects often experience failure to reach a stage of meaningful conflict because what the instructor considers meaningful cannot be considered meaningful for them [48].

In the realm of science education, an individual is encouraged to be a scientist characterized by the mastery of scientific attitudes. PSESTs, therefore, are supposed to be open-minded even if the new conceptions lead to a change of thinking mode and dismissal of 'recently proven invalid conceptions' [49]. In general, the research results regarding PSESTs' open-mindedness imply that they become more tolerant towards new ideas and realized that science itself contains tentative information. This finding is further supported by the increase of their average open-mindedness score from 75.4 in the initial condition to 77.2 in Cycle I. Individual's critical thinking ability holds prerequisite position for his open-mindedness. Critical thinking, which is also known as reflection, occurs before an individual decides to accommodate or assimilate new conceptions and it plays as the gate of open-mindedness [38].

Science does develop by either adding or removing pieces of inventory in individual's conceptual warehouse [12]. Yet individual experiences the task of establishing a reflective equilibrium between facts, new notions, and discovery and her own set of concepts. Science is also about one's adjustments to the new concepts and how equilibrium results [47]. The research results concerning inventiveness show that PSESTs' average scores increased from 72.2 in the initial condition to 76.7 in Cycle I. This finding implies that, in general, PSESTs considered new concepts as inventions. Thus, CCM increased PSESTs' inventiveness. Table 1 briefly compares PSESTs' scientific attitudes in the initial condition and Cycle I.

Table 1. The comparison of PSESTs' scientific attitudes in the initial condition and Cycle I

Aspects of Scientific Attitudes	Initial condition		Cycle I		Difference Cycle I vs initial condition
	Average score	Category	Average score	Category	
Curiosity	74.2	Fair	77.4	Fair	3.2
Critical thinking	70.4	Fair	75.8	Fair	5.4
Inventiveness	72.2	Fair	76.7	Fair	4.5
Respect for evidence	72.2	Fair	82.8	High	10.6
Open-mindedness	75.4	Fair	77.2	Fair	1.8
Cooperativeness	73.7	Fair	78.7	Fair	5
Perseverance	70.7	Fair	72.4	Fair	1.7
Social sensitivity	73.2	Fair	75.4	Fair	2.2
Average	72.8	Fair	77.1	Fair	4.3

Another focus in the implementation of CCM was an attempt to reduce PSESTs' misconceptions. Table 2 explains the data regarding the change of PSESTs' misconception rate. From Table 2, we can infer that all of the misconceptions reduced in all of the topics of the course.

Table 2. The change of PSESTs' misconceptions in the pretest and the posttest in Cycle I

Categories and misconceptions	*n* and % of PSEST in the pretest	*n* and % of PSEST in the posttest
1. The characteristics of living things		
a. All living things can actively move	9 (23.1%)	2 (5.1%)
b. Mushrooms belongs to plant kingdom	12 (30.8%)	2 (5.1%)
c. Plants exhale O_2 and inhale CO_2	22 (56.4 %)	3 (7.7%)
d. Plants rely on air, water, sunlight and inorganic minerals as their food	30 (76.9%)	2 (5.1%)
e. Organisms grow bigger because their cells grow bigger	7 (17.9%)	2 (5.1%)
The average of misconception incidence	16 (41%)	2.2 (5.6%)
2. The levels of organization of living things		
a. A virus is a unicellular organism	16 (41%)	2 (5.1%)
b. All cells have nuclei	38 (97.4%)	3 (7.7%)
c. A tissue is a collection of cells with identical shape	25 (64.1%)	7 (17.9%)
d. A food chain is always started by autotrophic organism	39 (100%)	2 (5.1%)
e. There are more herbivores than carnivores because people tend to breed herbivores	9 (23.1%)	0 (0.0%)
The average of misconception incidence	25.4 (65.1%)	2.8 (7.2%)
3. The human movement system		
a. The humans have the same number of bone throughout their lives	21 (53.8%)	1 (2.6%)
b. Meat and muscle are different	3 (7.7%)	3 (7.7%)
c. Involuntary movement is not controlled by the brain	10 (25.6%)	0 (0.0%)
d. Bones are not living	2 (5.1%)	0 (0.0%)
e. Disease like osteoporosis or arthritis affect only old people	10 (25.6%)	0 (0.0%)
The average of misconception incidence	9.2 (23.6%)	0.8 (2%)
The overall average of misconception incidence in Cycle I	16.9 (43.2%)	1.9 (4.9%)

3.2.3. Reflect. The collaborating lecturer gave two suggestions to be implemented in Cycle II. The first suggestion was PSESTs were required to bring scientific encyclopedias and elementary school textbooks in order to spot misconceptions in common textbooks. The second suggestion was that the lecturer should be more assertive and sterner in dealing with PSESTs who did not seriously follow and disrupted the courses. The suggestions were then planned to be accommodated in Cycle II. PSESTs, in the next meetings, would be involved in supplemental activities: detecting and criticizing misconceptions from various elementary school textbooks.

3.3. Result and Discussion Concerning Cycle II

3.3.1. Plan. The planning step of Cycle I primarily focused on revising the course plans. The revision has been done by incorporating collaborating lecturer's suggestions from the reflect step of Cycle I.

3.3.2. Act and observe. Generally, the individual's scientific attitudes in Cycle II were improving compared to Cycle I. The number of PSEST possessing low, fair, and high scientific attitudes were 1, 20, and 18, respectively. The change of scientific attitudes needs also needs to be compared. Table 3 visualizes the changes.

Table 3. The comparison of PSESTs' scientific attitudes in the initial condition, Cycle I, and Cycle II

Aspects of Scientific Attitudes	Initial condition		Cycle I		Cycle II		Difference Cycle I vs initial	Difference Cycle I vs Cycle II
	Average score	Category	Average score	Category	Average score	Category		
Curiosity	74.2	Fair	77.4	Fair	85.2	High	3.2	7.8
Critical thinking	70.4	Fair	75.8	Fair	80.2	Fair	5.4	4.4
Inventiveness	72.2	Fair	76.7	Fair	81.7	Fair	4.5	5
Respect for evidence	72.2	Fair	82.8	High	85.4	High	10.6	2.6
Open-mindedness	75.4	Fair	77.2	Fair	83.2	High	1.8	6
Cooperativeness	73.7	Fair	78.7	Fair	78.8	Fair	5	0.1
Perseverance	70.7	Fair	72.4	Fair	79.8	Fair	1.7	7.4
Social sensitivity	73.2	Fair	75.4	Fair	77.2	Fair	2.2	1.8
Average	72.8	Fair	77.1	Fair	81.4	Fair	4.3	4.3

The trends about misconception incidence in Cycle II are the same as that of in Cycle I. CCM successfully reduced all of the misconceptions about the human respiratory system, the human blood circulatory system, and the human digestive system.

Table 4. The change of PSESTs' misconceptions in the pretest and the posttest in Cycle II

Categories and misconceptions	*n* and % of PSEST in the pretest	*n* and % of PSEST in the posttest
1. The human respiratory system		
a. Respiration and breathing are interchangeable concepts	35 (89.7%)	3 (7.7%)
b. The inhaled gas moves through gullet	3 (7.7%)	0 (0.0%)
c. Human solely inhales oxygen and exhales carbon dioxide	38 (97.4%)	2 (5.1%)
d. Respiration occurs in the lungs and is solely the process of gas exchange	34 (87.2%)	0 (0.0%)
e. The heart is one of the organs in the human respiratory system	2 (5.1%)	0 (0.0%)
The average of misconception incidence	22.4 (57.4%)	1 (2.6%)
2. The human blood circulatory system		
a. All arteries are carrying oxygen-rich blood	38 (97.4%)	15 (38.4%)
b. All veins are carrying carbon dioxide-rich blood	38 (97.4%)	14 (35.9%)
c. A couple having the same blood type will always produce children with identical blood types to their parents	21 (53.8%)	0 (0.0%)
d. Blood is produced in the heart	5 (12.8%)	0 (0.0%)
e. Oxygen-rich blood circulates in the left side of the body whilst the carbon dioxide-rich blood circulates in the right side of the body	13 (33.3%)	1 (2.6%)
The average of misconception incidence	29.5 (58.9%)	6 (15.4%)
3. The human digestive system		
a. The human digestive and circulation system have no relationship	30 (76.9%)	0 (0.0%)
b. The process of releasing usable energy from food happens in the digestive system	35 (89.7%)	1 (2.6%)
c. The digestive system starts in the stomach	2 (5.1%)	0 (0.0%)
d. Muscles and brain are not involved in the digestive system	7 (17.9%)	0 (0.0%)
e. The process of releasing feces through the anus is called excretion	29 (74.4%)	1 (2.6%)
The average of misconception incidence	20.6 (52.8%)	0.4 (1%)
The overall average of misconception incidence in Cycle II	22 (56.4%)	2.5 (6.4%)

4. Conclusion

The implementation of CCM can improve PSESTs' scientific attitudes and reduce the incidence of scientific misconceptions. CCM as the teaching intervention remedied the misconceptions-related problems faced by PSESTs of A4 class at PGRI University of Yogyakarta and gave supplemental shreds of evidence supporting earlier studies about the efforts of improving scientific attitudes and reducing misconceptions through the implementation of CCM. Lecturers must view misconception problem as a two-faceted urgency: reorganising or replacing subjects' conceptions and establishing subjects' resilience against misconceptions, which will possibly appear in the future, by improving scientific attitudes.

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