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Investigating Students' Conception of Acid-Base Indicators Using Three Scientific Questions-Enhanced Conceptual Change Model

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Abstract: Investigating Students' Conception of Acid-Base Indicators Using Three Scientific Questions-Enhanced Conceptual Change Model. Objectives: The aims of this research is to obtain the results of the analysis process and changes in students' conceptions on acid base indicators concept from the implementation of the conceptual change model enriched with three scientific questions (CCM-EWTSQ). The stages of CCM-EWTSQ are verification of misconceptions, creation of cognitive conflict conditions, providing assistance for equilibration, and reconstruction of final understanding. **Methods:** The research is using mixed methods which immersed quantitative research into qualitative research. The research subjects were students of the Chemistry Education Study Program, which consisted of four test students on the concept of acid-base indicators. The data obtained were analyzed descriptively qualitatively. **Findings:** The results of this study are as follows. Based on the results of two misconceptions verification, students found misconceptions about the concept of acid-base indicators (4 students). Each individual (research target) has undergone a process of changing cognition or conception in each stage of the CCM-EWTSQ on concept that students learn. The roadmap of changes in conception from stage to stage of CCM-EWTSQ experienced by each individual cannot be equated. The implementation of CCM-EWTSQ has succeeded in reducing the misconception of prospective chemistry teacher students who have verified misconceptions. **Conclusion:** Not all individuals who were verified had misconceptions at first and then turned into concept-aware after proceeding with CCM-EWTSQ

Keywords: misconception, CCM-EWTSQ, CCMo, accommodation.

▪ INTRODUCTION

The problem of chemical misconceptions is not only found in Indonesia but occurs globally, without being limited by the level of development of a country (Majeed et al, 2023). Chemical misconceptions not only occur among students and students but also among chemistry teachers. The chemical concepts that are understood with misconceptions (MK) by a large number of students, students and teachers vary, not just one chemical concept. Suparno (2005) stated that one of the causes of misconceptions that occur in students is the teacher. The source of this cause is related to the place of study at each university which plays a less important role. The academic role of each university of origin should be realized in the form of developing a clinical treatment model for students of the Chemistry Education Study Program who have been verified by MK on the concept of acid-base indicators. This clinical treatment is intended to change students' conceptions from misconception status to understanding the concept.

Referring to Taber (2002), researchers try to take on the role of educators as learning doctors. In handling chemistry MK for students, researchers started by diagnosing the students' conception status. When the diagnosis results find misconceptions students, researchers will use this information to provide prescriptions or actions, namely by designing learning that is curative (remediation). Misconception remediation actions recommended by Taber (2002) and Osborne (1982) are not carried

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out classically, but are handled individually. Curative handling of chemistry MK for students can be done using a conceptual change strategy (Pabuccu & Geban, 2006).

Conceptual change strategies play an important role in addressing misconceptions that have been embedded in students' cognitive structures (Sumarni & Siadi, 2012). Through this approach, students are encouraged to explore and question their erroneous conceptual understandings. Key stages in conceptual change strategies, such as the creation of cognitive conflict and conceptual reconstruction, help students to actively examine, evaluate, and modify their erroneous concepts. By using this strategy, students do not simply memorize new information, but are involved in the process of investigating and reconstructing their understanding. This student-centered approach allows them to build a more accurate, consistent, and durable understanding of scientific concepts. In addition, conceptual change strategies also encourage students to develop critical thinking and metacognitive skills, which are very important in science learning (Muhali, 2018).

Stenhouse (1986) wrote the operational stages of a conceptual change strategy as follows. The first stage, reveals students' initial conceptions (reveals students' MK). The second stage displays the scientist's conception. The third stage, students' initial conceptions are contrasted with scientists' conceptions so that dissonance or cognitive conflict occurs. The fourth stage, the learner and the students try and find arguments, data, experimental results that direct students to be more in favor of a new conception that is in accordance with the scientist's conception. The fifth stage, encourages or encourages students to be willing to let go of old conceptions and accept new conceptions. If these five stages are successful, the student is willing to let go of the old conception and accept the new conception, then it is declared that a conceptual change has occurred. This phased sequence is also found in the article written by Effendy (2002). The stages whose order cannot be changed can be interpreted as syntax in the learning model. Based on this statement, researchers use the conceptual change model (CCM) terminology which can represent conceptual change strategies.

The implementation of CCM which is administered in text form based on the above thinking is presented as follows. Figure 1 represents the results of the analysis of seven conceptual change text (CCT) documents that have been developed by previous researchers.

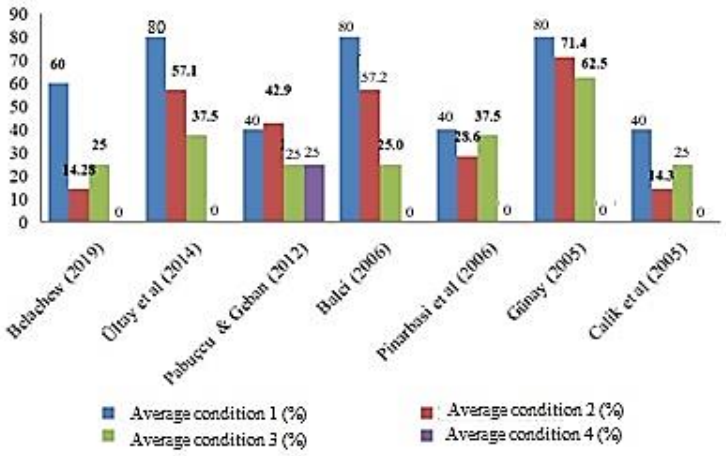

Figure 1. Four conditions for the accommodation process to occur in the brain schema

Figure 1 shows that the CCT implemented by Belachew (2019), Ultay et al. (2014), Balci (2006), Pinarbasi et al. (2006), Gunay (2005), and Calik et al. (2005) does not facilitate conditioning that the four new concepts obtained will provide benefits. When this fourth condition is not fulfilled, CCT becomes ineffective and is proven to still leave a percentage of student misconceptions of 20%. Figure 2 represents the results of the analysis of the four conceptual change modules (CCMo) that have been developed by Suyono and Muchlis (2017).

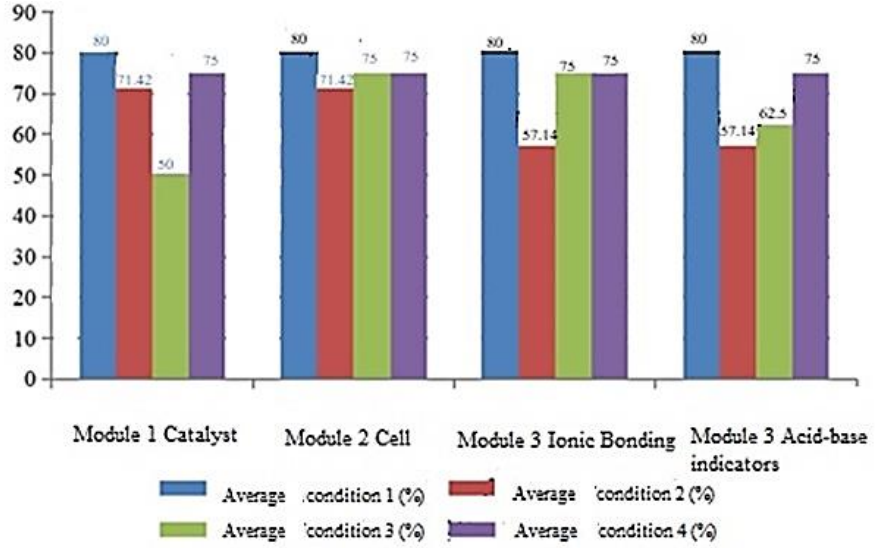

Figure 2. Four conditions for accommodation in four CCMos

Based on Picture 2, the first conditioning, namely dissatisfaction with the existing conceptions in the four modules, is very good with an average score of 80%, as well as the fourth conditioning (a new conception must be useful) is good with an average of 75% (above 70%), meaning the first conditioning and fourthly, it has fulfilled what Posner requires in assisting with student accommodation. The second conditioning (a new conception must be understandable) in the four modules developed still has an average of 64.28% (under 70%), then in the third conditioning (a new conception must make sense) the average of the four modules is 66%. This indicates that the four modules that have been prepared have not been optimal in fulfilling Posner's accommodation conditions. Based on the facts above, the novelty of this research is improvised the implementation of CCM which the researcher then named conceptual change model enriched with three scientific questions (CCM-EWTSQ). This improvisation is aimed at ensuring that the MK status experienced by students who will be remediated is true. Researchers are aware of the need to be careful in determining (convicting) someone of MK status. The second improvisation in CCMo that was developed was administering the creation of cognitive conflict conditions twice. Researchers realize that the occurrence of cognitive conflict is the key to the accommodation process and the accommodation process is the core of CCM.

In this research, it will be reported "How students' conceptions change in implementing conceptual change models enriched with worksheets based on three scientific questions (conceptual change model-enriched with three scientific questions,

CCM-EWTSQ) as an effort to reduce misconceptions among prospective chemistry teacher students based on four conditions Posner accommodation?"

▪ METHOD

This research uses mixed method design, which combines qualitative and quantitative methods (Creswell, 2012; Fraenkel & Wallen, 2012). The combined model chosen was concurrent embedded, between qualitative and quantitative methods carried out at the same time (Creswell, 2012). In this research the primary method is a qualitative method, especially in obtaining anaysis results regarding the cognitive processes of target students at each stages of the CCM-EWTSQ. CCM-EWTSQ is administered in two supporting tools, namely CCMo and worksheet. The conceptual change module (CCMo) that researchers developed is different from the CCMo developed by previous researchers. Two improvisations were made by researchers in developing CCMo. The first improvisation, the student MK status verification stage was carried out twice. In addition, the researchers completed CCMo which was developed to facilitate efforts to improve the weaknesses of accommodation conditioning two and three. This action is taken to prevent weaknesses that have occurred previously (see Figure 1) from recurring. Researchers overcome this weakness by providing visualization images, diagrams, graphs, or virtual laboratories, considering that visualization or modeling is important for second and third conditioning. The four CCMos developed by researchers have been assessed for validity by five experts in the field of chemistry learning. The results of the expert judgment provided by the five validators came to the conclusion that the four CCMos developed were very valid for use in supporting the implementation of CCM-EWTSQ.

The subjects in the research were 35 students that final semester students in the Undergraduate Chemistry Education Study Program at FMIPA Unesa (class of 2018) who were identified as having a burden of chemistry MK and were verified to have experienced MK on the concept of acid-base indicators. Furthermore, we choose four students to facilitate the analysis process, student identity coding was created, such as MA, MB, MC, and MD. Apart from researchers, the supporting instruments used in this research are CCMo, worksheets and chemical conception diagnostic test sheets on the four chemical concepts studied. The test consists of 16 questions with every indicators (Appendix 1) used in this study.

The data collection techniques used in this research were observation, documentation and diagnostic tests. Data tringulation as a characteristic of qualitative research is certainly carried out by researchers. Researchers also quantify qualitative (attributes) to help make decisions (conclusion). Thus, the secondary method as support is a quantitative method. This triangulation shows special dominance when answering the second and fourth elementary problem formulations. The quantitative research design using the time series experiment (Creswell, 2012; Fraenkel & Wallen, 2012) as shown in Figure 3 is more devoted to answering the first and third elementary problem formulations.

Pre-Test	Treatment	Post-Test
O_1. O_2. O_3	X	O_4. O_5. O_6

Figure 3. The time series experiment research design

Information: O1, O2, O3, O4, O5, O6= Testing student conceptions from stage to stage in CCM-EWTSQ, X = implementation of CCM-EWTSQ.

Data analysis techniques are the process of collecting data systematically to make it easier for researchers to obtain conclusions. The analysis in this study consists of: data reduction, data presentation, drawing conclusions/verification (Miles & Huberman, 1994).

▪ RESULT AND DISSCUSSION

Initial Condition of Research Target Students

Table 1 presents supporting evidence that 4 people with code names MA to MD should be involved in implementing improvements to chemistry MK using CCM-EWTSQ for each of the concepts studied.

Table 1. Results of the diagnostic test on conception of research target students

No.	Student name	Number of Concepts Understood			Researcher's Decision
		TK	TTK	MK	
1.	MA	10	1	5	Remediation
2.	MB	11	0	5	Remediation
3.	MC	9	4	3	Remediation
4.	MD	9	4	3	Remediation

None of the students targeted by the remediation program had 100% mastery of the tested chemistry concepts. This indicates that these students have an uneven or imperfect understanding of the tested chemistry concepts. This indicates a gap or deficiency in mastery of the material that needs to be addressed through the remediation program. Each individual who is designated as the target of the CCM-EWTSQ application has the potential to know the concept so that the opportunity for unique things to happen during the concept change process is very possible as found by previous researchers.

Although no one achieved 100% mastery, this study shows that every student has the potential to learn and master the tested chemistry concepts. This means that the remediation program has the potential to succeed if implemented properly. According to Disessa (2002), the process of conceptual change in students can involve unique and unexpected things. This finding implies that the remediation program must be flexible and responsive to the individual needs of students, considering the possibility of unique patterns in conceptual change. In addition, the CCM-EWTSQ method is one of the approaches used in the remediation program. So the results of this study indicate that this method has the potential to help students improve their conceptual understanding, although further adjustments and evaluations are still needed.

Changes in Student Conceptions at each CCM-EWTSQ Stage

Table 2. Changes in student a's conceptions at each CCM-EWTSQ stage no. stages of student condition & conception

No.	Stages	Conditions and Conceptions of Students
1	Before entering the remediation program using CCM-EWTSQ (screening stage)	Of the 16 questions regarding the concept of acid-base indicators, 10 items were understood by TK, 1 item by TTK, and 5 items by MA. This student's MK degree is 31.25%.
2	Verifikasi konsepsi pertama	MA verified by MK
	Second conception verification	The definition written by MA does not match the definition agreed upon by chemical scientists. Based on the results of the first and second verification, MA was declared a student who experienced MK on the concept of acid-base indicators
3	Creation of the first cognitive conflict	MA experiences cognitive conflict at a moderate level. Whatever the level, MAs are students who are affected by the creation of cognitive conflict in the first way. Efforts to create cognitive conflict as one of the stages in CCM-EWTSQ have succeeded in preparing changes in the MA conception
	Creation of a second cognitive conflict	MA experiences cognitive conflict at a very high level. MA felt surprised because his understanding was different from the understanding of scientists and MA stated that he was not comfortable with the definition that had been made with a very high level of confidence, so MA decided to abandon the old conception and wanted to accept the conception held by scientists. MA is a student who is affected by the creation of cognitive conflict in the second way
4	Providing assistance for equilibration, standards	MA has a status of full understanding (100%) of the concept of acid-base indicators. MA answered nine questions correctly out of the nine questions asked by the researcher. The process of equilibration of the acid-base indicator concept can be stated to have occurred in the MA cognitive structure
	Providing assistance for equilibration and enrichment	The MA, who at the end of providing assistance for the first equilibration (standard) was declared to have the status of full understanding (100%) of the concept of acid-base indicators, still has a correct understanding of the concept (still TK) at the end of providing the second assistance. MA experienced the failure to fully understand the dimensions of epistemology and axiology. The concept of acid-base indicators has been internalized in MA's cognitive structure. Will the internalization of conceptions without a strong understanding of epistemology and axiology have an impact on the process of reconstructing conceptions in MA's cognitive structure?
5	Reconstruction of conception	The degree of reconstruction of acid-base indicator conception in MA reached 57%. MA experiences incomplete conceptual reconstruction in his cognitive structure. Reconstruction was only partially successful in MA's cognitive structure. Verified MA experienced sufficient levels in late conception reconstruction.

Before participating in the remediation program using CCM-EWTSQ, student A (MA) showed a low level of understanding of the concept of acid-base indicators, only 31.25% of the total 16 questions were well understood. In the first conception verification stage, MA was verified to have a misconception (MK) related to the concept of acid-base indicators. In the second conception verification, the definition written by MA did not match the definition agreed upon by chemical scientists. In the creation of the first cognitive conflict, MA experienced a cognitive conflict at a moderate level. Efforts to create cognitive conflict as one of the stages in CCM-EWTSQ succeeded in preparing for changes in MA's conception. In the creation of the second cognitive conflict, MA experienced a cognitive conflict at a very high level. MA was surprised because his understanding was different from the understanding of scientists and decided to abandon the old conception and accept the conception held by scientists.

After the provision of assistance for the first equilibration (standard), MA achieved a full understanding status (100%) of the concept of acid-base indicators. However, after the provision of assistance for the second equilibration and enrichment, MA still had a correct understanding of the concept, but failed to fully understand the epistemological and axiological dimensions. The level of reconstruction of the acid-base indicator concept in MA only reached 57%. MA experienced incomplete conceptual reconstruction in its cognitive structure. This finding suggests that the process of conceptual change in MA involves unique and unpredictable dynamics, including various levels of cognitive conflict, conceptual understanding, and conceptual reconstruction. This emphasizes the need for a flexible and responsive approach in supporting students' conceptual change. This is in line with Taber's (2001) research which identified various levels and types of misconceptions that can hinder conceptual change, as well as the need for a flexible approach in supporting learning. In addition, Vosniadou (2007) said that a responsive approach and consideration of contextual factors are needed in supporting conceptual change.

The data presented in Table 2 and for 3 other students in the same concept (students coded MB to MD) have similar patterns. A resume of changes in the target students' conceptions of remediation of the ion bond concept using CCM-EWTSQ is presented in Table 3.

Table 3. Changes in respondents' conceptions on the concept of acid-base indicators

Students	Changes in Respondents' Conceptions on the Concept of Acid-Base Indicators						
	First Verification	Second Verification	First cognitive conflict	Second Cognitive Conflict	Standard equilibration	Equilibration with worksheets	Reconstruction
MA	MK	MK	Currently	Currently	Full	Full	Enough
MB	TK	MK	Low	Combination	Not Full	Not Full	Very less
MC	TK	MK	Very high	Very high	Full	Full	Enough
MD	MK	TK	Currently	High	Full	Full	Very less

Figure 3 shows a series of stages in the remediation program using CCM-EWTSQ (Conceptual Change Model - Exploration of Worldviews, Thoughts, Satisfactions, and Queries) to overcome misconceptions in students related to the concept of acid-base indicators. It began with students M0 and MP showing a low level of understanding of the concept of acid-base indicators before participating in the remediation program.

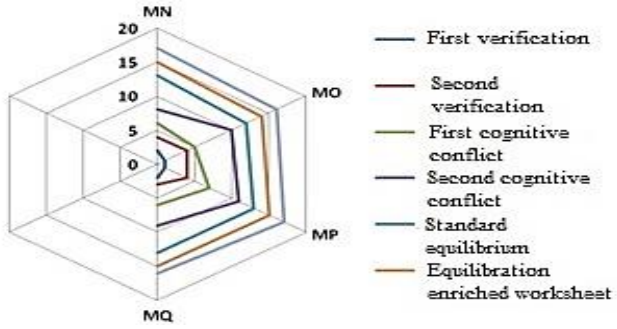

Figure 3. Changes in target students' conceptions of the concept of acid-base indicators

Verification of the first and second conceptions confirmed that M0 and MP had misconceptions related to the concept. Then, the process of creating the first and second cognitive conflicts was successfully carried out on M0 and MP, with varying levels of conflict. After providing assistance for equilibration (standard) and enrichment, M0 achieved a full understanding (100%) of the concept of acid-base indicators. However, MP still failed to fully understand the epistemological and axiological dimensions. It ended with the level of reconstruction of the acid-base indicator conception in MP only reaching 57%, indicating incomplete conceptual reconstruction.

In the first verification, MA and MD were in MK status. In the second verification of target students (MA to MC) MK. At the stage of creating conditions for cognitive conflict (desonance) is carried out twice. When creating the first and second cognitive conflict conditions, MC was at a very high level of conflict. Such students have a very high chance of changing their wrong conceptions (MK). In the standard equilibration stage, full understanding occurs in MA, MC, and MD. In enrichment equilibration, full understanding occurs in MA, MC, and MD, but does not occur in MB. This is evidence of the uniqueness of changes in individual cognition during the process of changing conception. The final facts also show that at the reconstruction stage the final understanding, that stage by stage the CCM-EWTSQ has been processed in each individual's scheme as shown by changes in conceptions in individual students' schemes is very varied, MA and MC show changes after reconstruction at a sufficient level, while MB and MD post-reconstruction changes in final understanding are at a very poor level (old conceptions that are embedded dominantly in cognitive structures). This is in line with research by Treagust and Duit (2008) which states the importance of a flexible and responsive approach in supporting conceptual change, by considering individual differences in the change process.

▪ CONCLUSION

Based on the research results and discussions that have been presented, it can be concluded that the implementation of a conceptual change model enriched with three scientific questions (CCM-EWTSQ) is an individual-based chemical misconception remedial program that is proven to reduce the burden of misconceptions. The results in this study is the implementation of the conceptual change model enriched with three scientific questions (CCM-EWTSQ) has succeeded in reducing the burden of misconceptions among prospective chemistry teacher students, showing that the level of cognitive conflict is medium-high-very high, the equilibration process using both

standard and enrichment methods has occurred in the student's cognitive structure and the reconstruction of understanding was partially successful in the cognitive structure, the student still had a wrong conception. Next, the success of remedial learning in an effort to straighten out students' wrong conceptions is demonstrated by the implementation of CCM-EWTSQ learning, which also an impact on the final concepts has understood in kindergarten.

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