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The Effectiveness of Remediation Learning Strategy in Reducing Misconceptions on Chemistry: A Systematic Review

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Abstract: Misconceptions are defined as wrong ideas or views of a person's concept different from the scientific concepts formulated by experts in their field. It must be reduced immediately so as not to hinder the process of understanding the next interconnected matter. Reducing students' misconceptions can be done through remedial learning. This study aimed to describe the phase in processing information that causes students' misconceptions based on learning theory, describe the implementation of an effective remedial learning strategy to reduce misconceptions in chemistry, and describe learning media that can be integrated into remedial learning in chemistry. The method used in this study was the systematic literature review (SLR) by searching articles on the electronics journal database. The database used in this study was ERIC, Google Scholar, and Sinta from 2011 to 2021. Seventeen articles were found in 14 indexed journals (Scopus and Sinta). The data was analyzed by collecting the related articles, reducing them based on the research focus, displaying the data, and concluding. The result showed that students build their understanding through assimilation and accommodation. The disequilibrium between both of these aspects causes a misconception. It must be reduced immediately through remedial learning. Six remedial learning strategies can reduce misconceptions in chemistry effectively, i.e., POE, Guided Inquiry, MRCD, Ember, Conceptual Learning, and ECIRR. This effectiveness is due to the phase of creating cognitive conflict. Integrating Information and Communication Technology (ICT) interactive media in implementing remedial learning strategies has a positive impact because interactive media can visualize abstract concepts. Hence, the cognitive accommodation phase is more effective.

INTRODUCTION

Every graduate of secondary education units must have competence in three dimensions, i.e., attitudes, knowledge, and skills (Chan & Luo, 2021; Löfgren et al., 2020). One of the aspects referred to in the dimension of knowledge is having conceptual knowledge (Morris, 2020; Páez et al., 2019). One of the subjects in high school related to conceptual knowledge in Chemistry. Chemistry is a branch of science that studies matter and energy in terms of the properties, reactions, structure, composition, and energy changes that accompany the reaction (Chang & Overby, 2019). Chemistry is a material that includes three levels of representation, i.e., macroscopic, sub-microscopic, and symbolic (Johnstone, 1991; Nada et al., 2019; Uyulgan & Güven, 2021). The three levels of

representation must be balanced against each other. Johnstone (1991) explained that most chemistry learning in schools and colleges focuses on the symbolic level. This makes students have difficulty understanding the relationship between symbolic representations with macroscopic and submicroscopic representations. To understand chemistry completely, the three levels of representation must be balanced against each other. Based on Jusniar et al., (2020a), the existence of difficulty at one level of representation can affect the understanding process on another level and can cause students to experience misconceptions.

Misconceptions are defined as wrong ideas or views of a person's concept that is different from the scientific concepts formulated by experts in their field (Chi, 2017; Dhindsa & Treagust, 2012; Ibrahim, 2012; Khandagale & Shinde, 2021; Paul Suparno, 2013; Tas et al., 2015; Tsaparlis et al., 2018). One of the causes of misconceptions is the failure of students to construct the basic concepts of chemistry (prerequisite concepts). It can hinder understanding the next concept that is built on it. The following research by Jusniar et al., (2019) stated that misconceptions in stoichiometry (prerequisite concepts) could cause students to have difficulty understanding the material of chemical equilibrium and subsequently lead to misconceptions.

Misconceptions become a big obstacle in meaningful learning (Pabuccu & Geban, 2012). Ibrahim, (2012), in his book, explained that misconceptions are resistant and persistent. This is one of the factors why students' misconceptions are difficult to eliminate and can be carried over to the next level of education. This is following the result of a study in some countries, i.e., Indonesia (Erman, 2017; Jusniar et al., 2020); Turkey (Durmaz, 2018); Pakistan (Ilyas & Saeed, 2018); South Africa (Kibirige et al., 2014). Therefore, misconceptions must be identified and reduced earlier because they can interfere with subsequent concepts that are interrelated (Treagust, 2006).

Reducing students' misconceptions can be done through remedial learning. Mulyadi (2010) defined remedial learning as an attempt to change the wrong conception with an alternative to present a new concept that is correct and scientific. Based on the literature study, the efforts to reduce students' misconceptions about chemistry have been carried out by several researchers, such as; remedial learning using analogy strategy (Aprilia & Suyono, 2016; Praswidiarini & Suyono, 2015), using E-module (Maria Erna et al., 2021); using the worksheet (Fariki & Novita, 2021; Nasrudin & Azizah, 2020), Implementation of a computer application-based conceptual change text learning model (Islamiyah et al., 2019; Susilowati et al., 2019), conceptual change (Pabuccu & Geban, 2012); Pogil (Rizqiyah et al., 2020); MRCD (Harza et al., 2021; Widarti et al., 2021), EDI (Lu et al., 2018); and POE (Kibirige et al., 2014; Zakiyah et al., 2019). Although the efforts to reduce misconceptions continue to be carried out by researchers, the implementation of learning strategies is less effective. The effectiveness category can be seen from each individual's percentage of misconception reduction. In other words, there are still many students who still maintain their misconceptions even though remedial learning has been implemented. This indicated that the remedial learning process needed the right strategy and adapted to the material's content which is discussed.

The research done by Barke et al. (2009) and Saputra et al. (2013) concluded that one of the essential phases to shaking students' misconceptions is the phase of cognitive conflict. This is corroborated by research by Irwandani & Rofiah (2015) and Khomaria & Nasrudin (2016) that mentioned to overcome

students' misconceptions, teachers, must choose a learning model that can emphasize critical and analytical thinking processes to help them find their answers to a problem so their learning process can be more meaningful. To know the effectiveness of remedial learning strategies that can reduce misconceptions, we need an in-depth literature review related to this topic.

The underlying factor for this research is the need to improve the quality of education. One of them is viewed from the quality of students (their level of conceptual understanding). This article is expected to be able to contribute to researchers, teachers, and prospective teachers in the future so that they can implement a learning strategy that follows the content of the material which is delivered so that students' misconceptions can be prevented or students' misconceptions can be reduced so that they can fully know the concept (zero misconceptions). In addition, some previous research that has been reviewed in this article is expected to direct other researchers to research in the future.

Based on the description above, the main focus of this research is systematically synthesizing research articles from 2011 to 2021 to examine remedial learning strategies that are effective in reducing misconceptions in chemistry. These articles reviewed are from Scopus and Sinta indexed journals. The research questions are: (1) What phase is important in the information processing process that causes students' misconceptions based on the learning theory, (2) How effective is the implementation of remedial learning strategy in reducing misconceptions based on the percentage of misconceptions reduction, (3) What kind of learning media can be integrated into the remedial learning strategy in reducing students' misconceptions on chemistry.

METHOD

This study used the Systematic Literature Review (SLR) method. The SLR method is carried out by systematically identifying and reviewing journals (Kitchenham et al., 2009). The empirical study focused on this research is about implementing an effective remedial learning strategy to reduce misconceptions in the chemistry discipline at the school and college levels. The data collected in this research were directly collected through an online database, i.e., ERIC, Google Scholar, and Sinta from 2011 to 2021. The reviewed articles consisted of 17 articles regarding implementing the effective remedial learning strategy in reducing misconceptions. It uses four keywords, i.e., misconceptions in chemistry, reducing misconceptions in chemistry, eliminating misconceptions in chemistry, and overcoming students' misconceptions in chemistry.

The data used to answer research questions came from several international/national education journals indexed by Scopus and Sinta. The criteria for selecting data (articles) to be reviewed are; (1) focus on discussion about remedial learning strategies, (2) misconceptions of chemistry, (3) article publications in the last 10 years (2011-2021); (4) Scopus (Q1-Q4) and Sinta (S1-S4) indexed journals. By considering these criteria, the articles that identify misconceptions, the study of misconceptions from other disciplines, book publications, and thesis/proceedings would be eliminated.

In the initial searching process, 247 articles were obtained. Then the screening process was carried out according to the criteria above, then 17 articles were obtained from 14 indexed journals for analysis (Table 1). The article screening process until 17 articles was obtained for review can be seen in Figure 1.

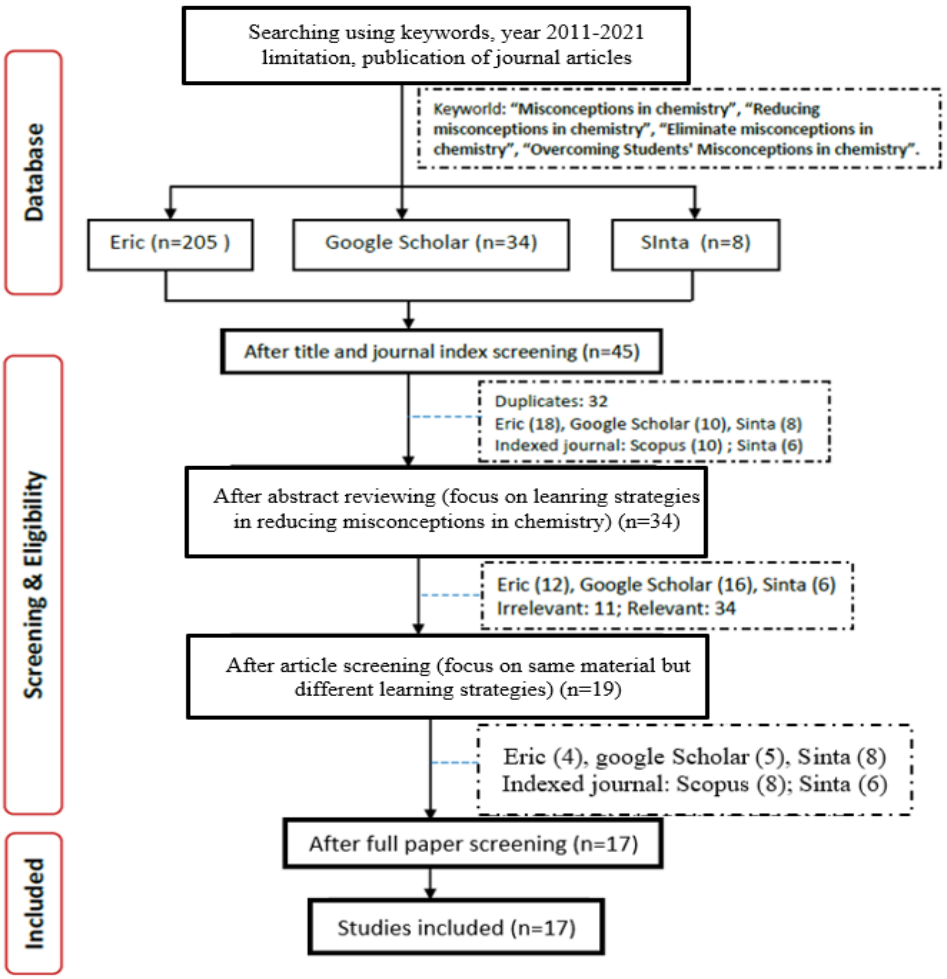

Figure 1. Flowchart of Article Screening Process

Table 1. Selected Articles and Journals

Selected Journal	Analyzed Article
Chemistry Education Research and Practice (Q1)	1. (Sendur & Toprak, 2013)
International Journal for Educational and Vocational Studies (Q1)	2. (Zakiyah et al., 2019)
International Journal of Science Education (Q1)	3. (Lu et al., 2018)
Jurnal Pendidikan IPA Indonesia (Q2)	4. (Nasrudin & Azizah, 2020) 5. (Widiarti et al., 2016)
International Journal of Innovative Science and Research Technology (Q2)	6. (Rizqiyah et al., 2020)
International Journal of Instruction (Q2)	7. (Jusniar et al., 2020)
International Electronic Journal of Elementary Education (Q3)	8. (Tas et al., 2015)
Journal Of The Serbian Chemical Society (Q3)	9. (Ozmen & Naseriazar, 2018)
International Journal Of Education (S1)	10. (Widarti et al., 2017)
Tadris: Jurnal Keguruan dan Ilmu Tarbiyah (S2)	11. (M Erna et al., 2020)
Journal of Education and Learning (S2)	12. (Maria Erna et al., 2021)
Jurnal Tadris Kimiya (S2)	13. (Rohmah & Virtayanti, 2021)
Al-Khwarizmi: Jurnal Pendidikan Matematika dan Ilmu Pengetahuan Alam (S3)	14. (Haryati & Oktaviani, 2021)
Unesa Journal of Chemical Education (S4)	15. (Islamiyah et al., 2019) 16. (Aprilia & Suyono, 2016)
Jurnal Penelitian Pendidikan Kimia (S4)	17. (Hastuti et al., 2014)

RESULT AND DISCUSSION

Misconceptions are defined as wrong ideas or views of a person's concept that are different from the scientific concepts formulated by experts in their field (Chi, 2017; Dhindsa & Treagust, 2012; Ibrahim, 2012; Khandagale & Shinde, 2021; Paul Suparno, 2013; Tas et al., 2015; Tsaparlis et al., 2018). Chemistry is a subject that is considered difficult, and it often occurs because of its complex and abstract concept. Durmaz, 2018 and Sirhan (2007) identified the causes of chemistry that are difficult to learn and provide opportunities for misconceptions, i.e., a) The material consists of macroscopic, symbolic, and sub-microscopic representation, b) students' working memory is overloaded due to the representation of information conveyed by the teacher is too much, c students, d do not easily understand) language and the terms used by the teacher or reading materials) students have not mastered fundamental concepts, e) students' low learning motivation.

Learning Theory Underlying the Occurrence of Misconceptions

The occurrence process of misconceptions is based on Piaget's theory of cognitive development. According to Piaget, concept acquisition is related to the formation and development of schemas or cognitive structures, whereby students intellectually adapt to the surrounding environment (Slavin, 2019). The schemas will continue in line with students' cognitive experience when adapting. This adaptation can be made in two ways, i.e., assimilation and accommodation.

Assimilation occurs when a stimulus (perception, concept, or new experience) has the same characteristics as a pre-existing schema (preconception). The stimulus can be directly integrated into an existing schema. This shows that the assimilation process involves merging the new schema with the existing schema. Accommodation occurs when the given stimulus does not match the existing scheme. When accommodation occurs, a person will (1) create a new schema to match the new stimulus or (2) modify the existing schema so that it fits the new stimulus (Suparno, 2013).

In cognitive development, balancing assimilation and accommodation is needed, which is called equilibrium. Someone will always try to carry out changing disequilibrium into equilibrium through assimilation and accommodation, which is called the equilibrium phase. To maximize the equilibration process, Piaget suggested giving challenging things to students so that cognitive conflicts occur in their minds (Slavin, 2019). The equilibration process can positively impact when the new subject matter can adapt to the existing cognitive structure. However, if the subject matter obtained is contrary to the cognitive structure or preconceptions, students will not be motivated to seek the truth of the concept. Their preconceptions can become resistant and persistent misconceptions (Ibrahim, 2012). The phase of cognitive development, according to Jean Piaget, can be illustrated in Figure 2.

Effective Learning Strategies in Reducing Misconceptions

Misconceptions are a very big obstacle in a meaningful learning process. Therefore it must be immediately reduced through remedial learning. The analysis result description of the effectiveness of remedial learning strategies from several articles is narrated as follows: The effectiveness of remedial learning strategies is based on the percentage of students' misconception reduction. To interpret its percentage, the criteria from Hake (1998) are used. Based on the results of the article analysis, several

trends in misconception reduction strategies that researchers most often use in the last 10 years, such as POE, guided inquiry, multi-representation learning with cognitive dissonance strategies (MRCD), Ember-r, using analogies, using learning interactive media, and worksheets. According to Hake's score interpretation, there are six remedial learning strategies with high effectiveness in reducing misconceptions on chemistry, such as POE, Guided Inquiry, MRCD, Ember, conceptual learning, and ECIRR. The analysis result description of the effectiveness of remedial learning strategies in more detail can be seen in Table 2.

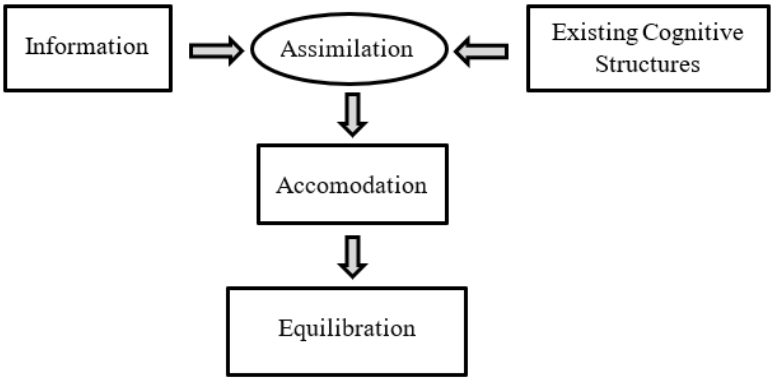

Figure 2. Piaget's Theory of Development Change

Tabel 2. The Remedial Learning Strategies to Reduce Misconceptions

Matter	Learning Strategy	% Reduction Misconceptions	Effectiveness	Article identity
Thermochemistry	POE	90.42 %	High	(Zakiyah et al., 2019)
Thermochemistry	Metacognitive-based worksheets	31.98 %	Medium	(Nasrudin & Azizah, 2020)
Thermochemistry	Guided Inquiry	73.52 %	High	(M Erna et al., 2020)
Redox Titration	MRCD	82.13 %	High	(Widiarti et al., 2016)
Acid-Base and Argentometric Titrations	MRCD	66.78 % and 67.13 %	Medium	(Widarti et al., 2017)
Reaction Rate	Conceptual Learning	82.16 %	High	(Sendur & Toprak, 2013)
Reaction Rate	Embe-r	72.3 %	High	(Jusniar et al., 2020)
Chemical Equilibrium	Pogil (Guided Inquiry)	69.45 %	Medium	(Rizqiyah et al., 2020)
Chemical Equilibrium	Conceptual Learning	44.44 %	Medium	(Ozmen & Naseriazar, 2018)
Chemical Equilibrium	Guided Inquiry	76.45 %	High	(Haryati & Oktaviani, 2021)
Solubility Equilibrium	Conceptual Learning	86.07 %	High	(Islamiyah et al., 2019)
Acid Base	ECIRR	97.00%	High	(Hastuti et al., 2014)
Acid-Base	Conceptual Learning	97.76 %	High	(Rohmah & Virtayanti, 2021)
Chemical Bonding	Analogies	55.77 %	Medium	(Aprilia & Suyono, 2016)

Based on Table 2, it is known that not all remedial learning strategies have high effectiveness in reducing misconceptions. One of the reasons is that the students have not learned meaningfully and have not succeeded in constructing information into correct concepts (Widarti et al., 2017). According

to Barke et al. (2009) and Ibrahim (2012), misconceptions are resistant and persistent or difficult to change and tend to persist.

The resistance to misconceptions can occur because of a disequilibrium state caused by a cognitive conflict process that has not reached an equilibrium state completely. An equilibrium state can occur if assimilation and accommodation are integrated. Suparno (2013), in his book, explained that through assimilation, students could adopt new schemes to existing schemes so that the schemes are not changed but only expanded; meanwhile, through accommodation, students can change the existing schemes to be matched with the newer scientific concepts so that both of the developing processes of cognitive structures can have done well.

The low percentage of reduction misconceptions after implementing remedial learning is not only caused by students who have difficulty representing submicroscopic phenomena but also due to their low mathematical ability (Nasrudin & Azizah, 2020; Ozmen & Naseriazar, 2018; Rizqiyah et al., 2020).

Implementation of Effective Learning Strategies in Reducing Misconceptions

Remedial learning with the POE strategy (Predict-Observe-Explain) effectively reduces misconceptions because POE facilitates students to investigate scientific phenomena in small groups and then make predictions about these phenomena (Predict). In this phase, the misconceptions can be identified. Furthermore, students observe and investigate predictions that do not match what is observed (Observe). This dissonance between predictions and observations causes students' cognitive conflicts to arise. Students can reconstruct their misconceptions at this phase by comparing predictions with observations (Explain) (Coştu et al., 2012; Zakiyah et al., 2019).

Remedial learning with the guided inquiry strategy has high effectiveness in reducing misconceptions. One of the success factors is that because guided inquiry learning is oriented to classroom activities, students at learning centers are required to explore their knowledge actively and be involved in each learning syntax. Inquiry is applied to assist students in elaborating thinking skills and constructing knowledge independently (M Erna et al., 2020; Haryati & Oktaviani, 2021).

Student-centered learning can make the information obtained by students more meaningful and stored in long-term memory. According to Hariyadi's research that mentioned the understanding of science concepts of students who the guided inquiry learning model teaches is higher than students taught by conventional learning Hariyadi et al. (2016). This showed that inquiry learning could be implemented in remediation learning. One of the important aspects of remediation learning is the student's motivation. Yuliastini et al. (2018) concluded that students who were taught using guided inquiry (POGIL) with the SSI context had the highest learning motivation compared to students who were taught using only POGIL or conventional learning.

Learning model multi-representation with cognitive dissonance strategy (MRCD) has a high level of effectiveness in reducing misconceptions (Widiarti et al., 2016). The MRCD model is implemented by giving two different representations to generate cognitive conflicts. The use of cognitive dissonance strategies can also lead to cognitive conflict in students. This phase can facilitate their conceptual change. Applying the cognitive dissonance strategy with the questions and answers method is important. The questions are presented in various representations to optimally the equilibration phase.

The ECIRR learning strategy has very high effectiveness in reducing misconceptions (Hastuti et al., 2014). It consists of four phases, i.e., (1) elicit phase, the teacher identifies students' misconceptions. (2) Confront phase, the teacher provides illustrations that do not match their understanding of the concept through cognitive conflict. This cognitive conflict process supports the students' equilibration process so that they can immediately construct their knowledge. The knowledge that has been constructed in the confront phase must be strengthened in the (3) identify phase. Students face an interactive demonstration so that they can realize their misconceptions in (4) the resolution phase. The teacher facilitates the equilibration process so that they can construct new correct conceptions in the (5) reinforce phase. The teacher asks students to draw how the concept has changed from the beginning until the teaching and learning process is complete, then proven by students doing practice questions. This phase is a reinforcement phase that is carried out repeatedly so that new concepts can be embedded in their cognitive schemes.

The Ember learning strategy has a high level of effectiveness in reducing misconceptions (Jusniar et al., 2020). This is because students face cognitive conflicts against their misconceptions. The conflict is pinned through the media for presenting experimental data or animated videos which do not match students' misconceptions.

Conceptual learning strategy has a high level of effectiveness in reducing misconceptions (Islamiyah et al., 2019; Kibirige et al., 2014; Rohmah & Virtayanti, 2021). Conceptual learning consists of four phases, i.e., identifying students' misconceptions, creating conceptual conflict, equilibration, and concept reconstruction. The existence of a conceptual conflict phase in students causes them to realize that their preconception is not following the scientific concept. False conceptions built up in the students' cognitive structure are first disequilibrated to be rearranged, then equilibrated to become the correct conception. The implementation of this conceptual learning strategy is based on Piaget's ideas and constructivism theory (Slavin, 2019).

Based on the analysis of the phases in the six remedial learning strategies that are effective in reducing misconceptions in chemistry, it can be concluded that the essential phase that can reduce misconceptions is the cognitive conflict phase which causes students to realize their misconceptions so that there is a restructuring of their ideas with correct scientific concepts. Changing the cognitive structure (scheme) that has been previously owned is adjusted to the external stimulus object. This change process can occur if there is a cognitive conflict (cognitive dissonance). If the cognitive dissonance is followed by a schema disequilibrium condition; overhaul; and realignment of schemas that reject old conceptions, individuals will automatically have a will to accommodate new, true concepts.

Integration of Learning Media in Remedial Strategies

Learning media is one of the external factors that can affect the learning process in the classroom. Kinds of learning media, according to (Sudjana & Rivai, 2005), are divided into; interactive media (computer-based) and non-interactive media (books, worksheets, etc.). The following are the results of the learning strategies analysis that researchers have carried out by integrating various kinds of learning media, as shown in Table 3.

Table 3. Integration of Learning Media in Remediation Learning Strategies

Matter	Learning Media	% Reduction Misconception	Effectiveness	Article Identity
Thermochemistry	Worksheet	31.98 %	Medium	(Nasrudin & Azizah, 2020)
Thermochemistry	Worksheet	73.52 %	High	(Zakiyah et al., 2019)
Reaction Rate	Worksheet	72.3 %	High	(Jusniar et al., 2020)
Chemical Equilibrium	Animated Video	76.45 %	High	(Haryati & Oktaviani, 2021)
Solubility Equilibrium	Web (software)	86.07 %	High	(Islamiyah et al., 2019)
Water Chemistry	Web (software)	85.00%	Medium	(Tas et al., 2015)
Salt Hydrolysis	E-module	42.47 %	Medium	(Maria Erna et al., 2021)
Redox Reaction	Practice Video	83.25%	High	(Lu et al., 2018)

The results in Table 3 show that the integration of interactive media in the implementation of remedial learning strategies can positively impact (Islamiyah et al., 2019; Jusniar et al., 2020; Lu et al., 2018; Tas et al., 2015). It is because interactive media can make it easier to communicate and visualize abstract chemical concepts (Saregar et al., 2013), so it is effective in the creation phase of cognitive conflict for students. Jegede & Akingbade, (2013) explained that the advantage of interactive media, i.e., that there is much multimedia content, more freedom of expression, and the delivery of material is clearer. Interactive media can make lessons more interesting, improve the quality of students' work, make students more active, and teachers have more various learning processes. This is following research was done by Maratusholihah et al. (2017) that explained learning using the Dual Situated Learning Model integrated with animation was able to prevent misconceptions better than the conventional approach, which was the percentage of students who experienced misconceptions about salt hydrolysis material in animation-integrated and conventional learning is 4.99 % and 11.87 %. Meanwhile, the buffer solution material misconceptions in animation-integrated and conventional learning are 9.37 % and 19.19 %.

The research by Erna et al. (2021) showed that the interactive media module's effectiveness was less effective in reducing students' misconceptions. This was because the application was not integrated with the remedial learning strategy. So that there are no phases of creating cognitive conflicts in students. Posner et al. (1982) stated that the remedial process must have a phase of students' cognitive creation to experience the first disequilibrate to be rearranged and then equilibrated into the correct conception.

CONCLUSION

Based on the results and discussions in this research, it can be concluded that the students build their understanding through the assimilation and accommodation process. The disequilibrium between both of these aspects causes a misconception. It must be reduced immediately through remedial learning to not hinder the process of understanding the next concept built on it. There are six remedial learning strategies with high effectiveness in reducing misconceptions in chemistry, i.e., POE, Guided Inquiry, MRCD, Ember, Conceptual Learning, and ECIRR. This effectiveness is due to the creation phase of cognitive conflict for students, so they can experience disequilibrate first and then be rearranged and equilibrated into the correct conception. The integration of interactive media in the implementation of remedial learning strategies has a positive impact because interactive media can visualize abstract concepts, so the

cognitive accommodation phase is more effective.

The existence of several misconceptions about chemistry matters. The teacher needs to eliminate it because misconceptions are resistant and persistent. If there is a misconception about prerequisite concepts, it can hinder understanding the next concept that is built on it. The characteristics of chemistry concepts are interconnected, so teachers are expected to explore students' prerequisite concepts before discussing new, interrelated concepts.

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