PERIÓDICO TCHÊ QUÍMICA
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ESTRATÉGIAS DE APRENDIZAGEM BASEADAS EM PROBLEMAS USANDO VÁRIAS REPRESENTAÇÕES E ESTILOS DE APRENDIZAGEM PARA MELHORAR AS COMPREENSÕES CONCEITUAIS DA QUÍMICA

PROBLEM-BASED LEARNING STRATEGIES USING MULTIPLE REPRESENTATIONS AND LEARNING STYLES TO ENHANCE CONCEPTUAL UNDERSTANDINGS OF CHEMISTRY

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RESUMO

Estudos na área de ensino de química descobriram que as estratégias de aprendizagem baseada em problemas (PBL) melhoram efetivamente a compreensão conceitual dos alunos. No entanto, há informações muito limitadas sobre a eficácia do PBL se ele for aplicado com representação múltipla (RM) para estudantes com diferentes preferências de aprendizado. Este estudo teve como objetivo provar os efeitos das estratégias de aprendizagem baseada em problemas (PBL) usando múltiplas representações (RM) e os estilos de aprendizagem dos alunos no entendimento conceitual em química. Havia duas aulas intactas no Departamento de Engenharia Mecânica do Politécnico do Estado de Bali que foram designadas para serem grupo experimental (n = 59) e grupo controle (n = 58). O Índice de Estilo de Aprendizagem (ILS) de Felder-Soloman foi aplicado para diferenciar as preferências de aprendizagem dos alunos, enquanto seu entendimento conceitual em química foi avaliado usando um teste após 6 semanas de tratamento. A análise de covariância (ANCOVA) mostra que a compreensão conceitual dos alunos ensinados usando estratégias de PBL com RM foi significativamente melhor do que aqueles ensinados usando apenas estratégias de PBL. Além disso, com base na variação dos estilos de aprendizagem, os alunos com estilo visual tiveram uma melhor compreensão conceitual do que aqueles com estilo verbal, mas a diferença não foi estatisticamente significativa. A ausência de efeito de interação entre estratégias de PBL com RM e estilo de aprendizagem na compreensão conceitual dos alunos sugere que o suporte de múltiplas representações nas estratégias de PBL pode efetivamente aprimorar a compreensão dos conceitos dos alunos em química, independentemente de seu estilo de aprendizagem.

Palavras-chave: *representações múltiplas, aprendizagem baseada em problemas, estilos de aprendizagem, química*

ABSTRACT

Studies in the area of chemistry teaching discovered that problem-based learning strategies (PBL) effectively improve students' conceptual understanding. However, there is minimal information about the effectiveness of PBL if it is applied with multiple representations (MR) for the students with different learning preferences. This study aimed to prove the effects of problem-based learning strategies (PBL) using multiple representations (MR) and students' learning styles on the conceptual understanding in chemistry. There were two whole classes in the Mechanical Engineering Department of Bali State Polytechnic that were assigned to be the experimental group (n=59) and control group (n=58). Felder-Soloman's Index of Learning Style (ILS) was applied to differentiate the students' learning preferences, while their conceptual understanding in chemistry was assessed using a test after 6 weeks of treatment. The analysis of covariance (ANCOVA) shows that the conceptual understanding of students taught using PBL strategies with MR was significantly better than those taught using PBL strategies only. Besides, based on the variation of learning styles, students with a visual style had a better conceptual understanding than those with verbal style, but the difference was not statistically significant. The absence of interaction effect between PBL strategies with MR and learning style on students' conceptual understanding suggests that the support of multiple representations in PBL strategies can effectively

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enhance students' understanding of concepts in chemistry regardless of their learning style.

Keywords: *multiple representations, problem-based learning, learning styles, chemistry*

1. INTRODUCTION:

Improving the quality of instruction is challenging for education institutions in Indonesia, especially vocational education, as a polytechnic, to generate human resources who can compete in a global age. Education at the Polytechnic prioritizes the application of practical aspects rather than theory. Chemistry, as one of the courses of theory in the field of mechanical engineering at the Polytechnic, faces challenges in the learning process that was implemented during this time because students who attend the program have a non-linear science field with chemistry. According to the majority of students, chemistry is difficult to understand, even though the application of chemical concepts in the field of mechanical engineering can support its competence in solving problems in the field such as corrosion control, the development of green energy, metal coating and waste treatment. Difficulties in understanding concepts in chemistry are related to student characteristics. Learning about chemistry needs a lot of conceptual understandings for students to be able to solve problems related to the thoughts which they learned. Conceptual understanding is a crucial aspect of instructional because the critical purpose of teaching is to help the student understand concepts in the subject matter as well as to explore a topic deeply (Santrock, 2011).

Complex challenges to understand concepts and to connect between concepts in finding new knowledge, require instructional strategies that are simple and useful for students. Chemistry is a complicated subject but has relevance and an essential role in engineering studies. Solutions to overcome these challenges through innovation in chemical learning include instructional strategies and media with new technologies that are contextual with the subject matter (Llorens-Molina & Pinto, 2014).

An instructional strategy is one or more procedures that are received by the individual to facilitate the learning task. Problem-based learning (PBL) is an instructional strategy that represents a significant change in the educational paradigm and recognized as a more proper way of education in the 21st century (Gwee, 2009). The characteristics of PBL are including, empowering learners to do research, encouraging them to integrate theory and practice and to apply knowledge and skill to resolve the real problem (Savery, 2006). PBL has two fundamental postulates. First, learning by problem-solving is more useful for the learner to create knowledge that can use in the future. Second, the learner would have problem-solving skills instead of memorizing (Barrows & Tamblyn, 1980). The implementation of the PBL strategy of instructional has a contribution to the development of learner's creative thinking skills. Enhancing individual's creative thinking is one of the high-level thinking skills. This is a crucial point because nowadays, there is a lot of individual needs to think creatively (Ersoy & Başer, 2014).

An important aspect of PBL strategy starts with the problem as the focus of the learning process that can encourage students to find information needed for problem-solving and to learn to integrate and organize data so that later, students can maintain and apply the knowledge while solving problems. PBL strategies involve the use of individual intelligence, human groups, and the environment to solve urgent, relevant, and contextual problems. In PBL strategies, understanding comes from interacting with problem scenarios and the learning environment, helping students to build their knowledge and thinking skills, involvement with problems, and the process of problem inquiry as well as social, collaborative processes (Tan, 2003). PBL strategies are complex real-world problems that motivate students to identify and research concepts and principles (Duch, Groh, & Allen, 2001). PBL is a good learning strategy to improve student academic achievement, to develop social skills, to be active in group discussions, and to become independent learners (Argaw *et al*., 2017). The PBL strategy has advantages compared to other learning strategies. PBL is very useful for increasing student knowledge, learning the results, and having a positive effect on their learning achievement (Maysaraa, 2016; Wilder, 2014; Yew & Goh, 2016).

Studies in the area of chemistry teaching discovered that PBL effectively improves students' conceptual understanding (Ayyildiz, & Tarhan, 2017; Bilgin, Şenocak, & Sözbilir, 2009; Günter & Alpat, 2016; Overton & Randles, 2015; Taşoğlu & Bakaç, 2014; Valdez & Bungihan, 2019; Yaayin, 2018). PBL offers chances for students to learn in a team, improve presentation skills, learn negotiating skills, and improve research skills as well as other skills (Mossuto, 2009). PBL enhances group activities, as well as improves students' soft and hard skills (Nurtanto *et al*., 2018). In the area of vocational education, especially in technical engineering, PBL as an instructional strategy was proven to be effective in accelerating the student's high-level skills in communication and the ability to apply new knowledge and skills corresponding to vocational education (Sada *et al*., 2015). Besides, PBL strategies would also increase professional awareness and communication skills (Jabarullah & Hussain, 2019). Problem scenario designed in PBL presenting real-world problems which are relevant to their professional field, which will encourage them to involve in the instructional topic and develop their understanding level to achieve the instructional objective.

Achieving the expected learning objectives is not only determined by the instructional strategies applied but also requires the delivery strategies in the representation of a concept. Students need support to integrate new ideas from a visualization with their prior knowledge (Garcia & Elene, 2014). Representation is also something that represents, visualize, and symbolize object and process (Goldin, 2002). Representational competence is a part of conceptual understandings that include the ability to explain a phenomenon and integrate new knowledge gained from various or multiple representations. Representational competence is a part of conceptual understandings that include the ability to explain a phenomenon and integrate new knowledge from multiple representations.

There are three functions of multiple representations. First, to give a presentation contains complementary information or to help to complete the cognitive process. Second, to limit mistake possibilities in interpreting other representations. And third, to help learners building deep situation concepts (Ainsworth, 1999). Multiple representations can encourage the learner to construct ideas genuinely and connect representations. The representations of chemical concepts consist of macroscopic level, sub-microscopic level, and symbolic (Johnstone, 1993). The macroscopic level refers to representation obtained through real experience, and that can see directly. The sub-microscopic level describes an abstract of the chemical phenomenon and explains the structure and process in the particle levels, and that cannot see directly. The symbolic level is a representation to identify entities using qualitative and quantitative symbolic language, such as chemical formulas, equations, stoichiometry. A representation is concluded as a way to express phenomena, objects, abstract concepts, ideas, processes, and mechanisms. Students can understand the concept of chemistry intact if they can connect representations at the macroscopic, sub-microscopic, and symbolic levels (Gilbert &Treagust, 2009). The success of understanding a concept in learning is not only influenced by the learning strategies and delivery that is applied, but is also influenced by students' learning styles in processing information.

Learning style refers to a group of psychological traits that determine how individuals perceive, interact, and respond emotionally to the learning environment (Heinich *et al*., 2002). It includes not only the cognitive aspect of learners but also the affective aspect, which makes it a reflection of learners' personality (Litzinger, 2007). Learning styles are closely related to the information design, format, and delivery method used in facilitating students in learning, understanding concepts, and problem-solving abilities. Therefore, it can be differentiated based on learners' sensory preferences. There are four dimensions of learning style, including; perception (sensing-intuitive), input (visual-verbal), processing (active-reflective, and understanding (sequential-global) (Felder & Silverman, 1988). This model is often used to study and identify the learning styles of students in science and engineering education.

Many strategies can be adapted to stimulate students to respond to learning materials based on their learning style preferences. Studies in the area of learning style found that it had a significant effect on chemistry learning achievement and student success and have distribution to improving the understanding concept (Murat, 2013; Olić & Adamov, 2018). Learning styles contribute positively to the improvement in efficiency, the effectiveness of the learning process, and the academic performance of students (Magulod, 2019; Sidiropoulou & Mavroidis, 2019). The learning style emphasized in this study is the verbal-visual dimension because it relates to multiple representations.

Based on the reviews, as mentioned above on PBL strategies, multiple representations, and learning styles, this study aims to investigate the effect of PBL strategies with the support of multiple representations and learning styles on students' conceptual understanding of chemistry.

2. MATERIALS AND METHODS:

2.1. Research Design

This study used a quasi-experimental research design to examine whether the effect of PBL strategies using multiple representations on students' conceptual understanding depends on their learning style. There were two whole classes in the Mechanical Engineering Department of Bali State Polytechnic that were assigned to be the experimental group (n=59) and control group (n=58). It was confirmed that all participants agreed to participate in this study. Based on the result of the pre-test, the control group gained a mean total score = 34.913, while the experimental group gained= 34.966. This result indicates that both classes had the same level of conceptual understanding and were eligible for the following experimental procedures. The experimental group was experiencing PBL strategies with multiple representations (MR), while the control group was implemented PBL strategies. Those treatment procedures were last for 6 meetings. Learning style compared in this study emphasizes on two dimensions, namely verbal-visual, acting as a moderator variable. The overall research subjects were male, with the majority were graduated from vocational high schools.

The outline of the research design is illustrated in Figure 1.

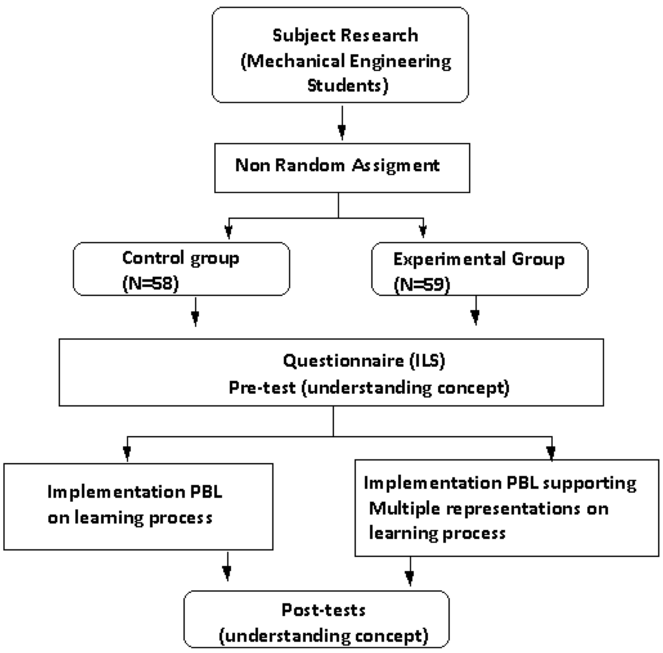

Figure 1. *Outline of Research Design*

2.2. Instruments

The instruments used to collect data were tests and questionnaires. The test consists of 25 multiple choice questions related to electrochemical concepts, such as oxidation-reduction reactions in electrochemical cells, the direction of electron movement in cells, cathode-anodes, reduction or oxidation reactions, energy changes, salt bridges, charge and recharge processes on batteries, mechanism of action fuel cell, corrosion process, and metal coating process (Appendix 1). This test has been regularly used to evaluate the students' conceptual understanding of chemistry in the Mechanical Engineering Department.

The questionnaire, consisting of 11 questions, was used to determine the subject's learning style, especially on the verbal-visual dimension. The questionnaire was adopted from the Index of Learning Style (ILS) developed by Felder and Solomon (North Carolina State University, Felder, & Soloman, 2020) (Appendix 2). The internal consistency reliability of the 11 verbal-visual dimension questions of ILS is .76 indicated by Cronbach Alpha coefficient (Litzinger *et al*., 2007).

2.3. Implementation of PBL Strategy

The topic of the chemistry subject given in this research is about electrochemistry. Learning outcomes based on the syllabus of applied chemistry course are students understanding and explaining oxidation-reduction reactions, potential standard cells, Voltaic cells, batteries, corrosion, fuel cells, electrolytic cells, electroplating. They can explain the difference between voltaic cells and electrolytic cells. Worksheets are given to students both in the control group, and the experimental group complimented with problem scenarios based on facts happened in the field, in the daily life and real problem, which related to the given subject matter. The real-life context of an applied aspect of chemistry in the learning scenario helps the students to identify the problem. The problem scenarios given to all groups are the same. The topics were selected from the news that occurs in the field and related to the electrochemical concept, as presented in Table 1.

Implementation of the PBL strategy in research adopted a set of rules (syntax) (Arends, 2012, p. 414). During the PBL implementation process, the instructor acts as a facilitator and motivator, who help the students to develop critical thinking skills, independent learning and build new knowledge as an effort to find solutions to problems. The detailed implementation of PBL Strategy in both the control group & experimental group is provided in Table 2.

The null hypotheses are formulated as follows:

1. There is no difference in chemistry conceptual understandings between the students in the control group and the experimental group
2. There is no difference in chemistry conceptual understandings between the students verbal and visual learning style
3. There is no interaction effect between PBL strategies and learning styles on chemistry conceptual understanding.

3. RESULTS AND DISCUSSION:

3.1 The Result of Learning Style Questionnaire

The results of the distribution of learning style questionnaires to all research subjects showed that most of the research subjects had visual learning styles, as shown in Table 3.

Table 3. *Students' based on Learning Style*

Groups	Learning Style		Total
	Verbal	Visual	
Control	13	45	58
Experimental	16	43	59

3.2. The Result of Control Group Activity

Strategy activities in the control group, based on the four givens, all information collected to find solutions to the problems identified and also complete the tasks contained in the worksheet. Some Problems were identified by each group, such as reactions that occur in batteries, reduction-oxidation reactions, differences between primary and secondary batteries, the difference between dry batteries and wet batteries, reactions in fuel cells, corrosion occurs in metals, electrolysis cells, and electroplating with chrome metal.

3.3. The Result of Experimental Group Activity

In the experimental group, the activities carried out were almost the same as the control class. Information is collected to find solutions to problems that have been identified, including macroscopic, submicroscopic, and symbolic aspects, for example, about electroplating mechanisms. Answering the question, the information collected is related to the electrode, the direction of the electron's movement in the coating process, the process of oxidation, and reduction. An Understanding process in chemical reaction requires visualization technology that can integrate into three levels of representation so that it can be presenting simultaneously. Therefore, in the experimental group to solve problems and answer tasks requires electrochemical multimedia modules that are supported by a dynamic visualization of abstract concepts.

3.4. The Effect of PBL Strategies with Multiple Representation and Learning Style on Students' Conceptual Understanding

Table 4 shows the pre-test result and also the post-test results from both of the groups after six meeting treatments. The post-test mean score of the control group is 60.759, and the experimental group is 74.711. In Table 5, the inferential statistical analysis using ANCOVA shows that the significance value of the applied PBL strategies on conceptual understanding in the post-test is 0.000 ($p < 0.05$). It means that the first null hypothesis is rejected. There were significant differences between the learning strategies (PBL) applied toward students' conceptual understanding.

The level of understanding of students' concepts measured by the score gained from the pre-test and post-test. The average scores of pre-test and post-test on electrochemical conceptual knowledge can be seen in Figure 2.

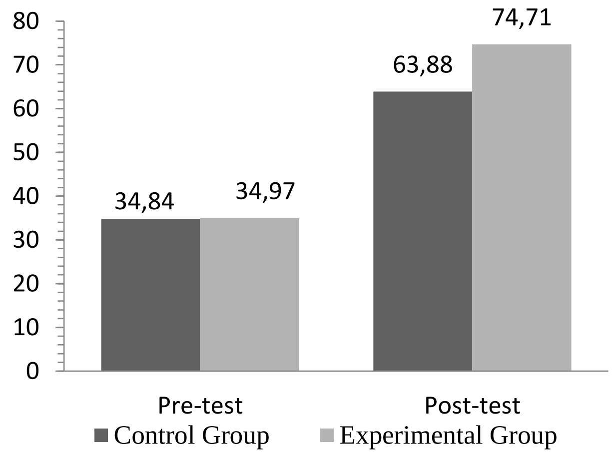

Figure 2. *The Average Scores of Pre-test and Post-test on Electrochemical Conceptual Understanding*

As shown in Table 5, the significance value of the learning style variables on conceptual understanding in the post-test is 0.962 ($p > 0.05$). It means that there is no enough evidence to reject the second null hypothesis. The differences of conceptual understanding between students with verbal and visual learning styles were not significant.

Figure 3 shows the gain comparison of the post-test results on electrochemical conceptual understanding based on instructional strategies applied and students' learning styles aspects. It shows that the discrepancy was only identified between the students taught using PBL and PBL plus multiple representation strategies. There is no meaningful score difference found between students with verbal or visual learning preferences.

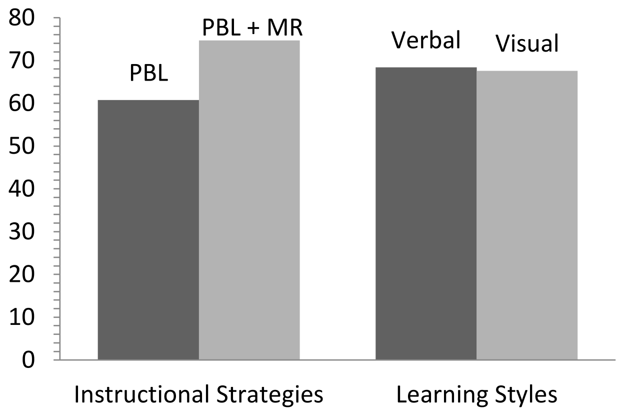

Figure 3. *The Post-test Results on Electrochemical Conceptual Understanding based on Instructional Strategies and Learning Styles Aspects*

To answer the third hypothesis, referring to Table 5, it can be explained that there was no interaction between PBL strategies with MR and learning styles toward conceptual understandings. In other words, support of Multiple Representations in Problem-Based Learning strategies can effectively enhance students' understanding of concepts in chemistry regardless of their learning style.

The implementation of PBL strategies with MR in learning has a positive effect on students' understanding of concepts in chemistry for mechanical engineering students. Presenting concrete facts about the application of chemical concepts in the field of mechanical engineering through the design of the scenarios provided is an attraction for students to learn to understand the concepts being studied. The plot designed is adapted to real situations that occur in everyday life and has to do with the concept of electrochemical material that can apply to the field of mechanical engineering. The instructor acts as a facilitator, motivator, and directs students who are divided into groups to make a hypothesis of the problem found by the scenario presented. Students in control and experimental groups seemed eager to follow the stages of the PBL implementation process. Fostering the ability to work together between individuals in a group is also an advantage of PBL.

The concept of electrochemistry is a material that is very applicable in the field of mechanical engineering. Having a good understanding of the concepts of chemistry, especially electrochemistry, will be able to support the competencies of students in developing their resources. The experimental group that was given the PBL strategy with the support of multiple representations gave better results to the improvement of understanding of the concept compared to without multiple representations. That is because Chemistry with scientific characters dominated by abstract concepts is very important to be supported by multiple representations in the chemistry learning process to minimize the difficulty of students understanding concepts.

Several research results have proven that multiple representations in chemistry learning have an important role in improving students' understanding of concepts and the quality of chemistry learning (Emine & Yakmaci-Guzel, 2013; Sunyono & Meristin, 2018). They learn science concepts; students need to understand various representations of scientific concepts, be able to translate between different representations, and demonstrate the capacity to construct representations in any form for specific purposes (Cheng & Gilbert, 2009). Understanding the concept of chemistry intact is if it can connect representations at the macroscopic, sub-microscopic, and symbolic levels. The combination of levels of representation (macroscopic, symbolic, and submicroscopic) can develop a deeper and more structured understanding of concepts (Baptista, *et al*., 2019).

Some applications of chemical concepts in the field of mechanical engineering can significantly support the competence of an engineer in developing his scientific resources. Engineering students are also expected to have an excellent conceptual understanding of basic science, including chemistry. Similar results also to find, the application of PBL in learning basic science for engineering students can improve conceptual understanding and an effective teaching pedagogy to enhance professional skills for engineering students (Beagon & NíFhloinn, 2018; Sahin, 2010). Multiple representations are essential in the study of chemistry, because learning chemical concepts, not only presented phenomena that can see with the naked eye but also abstract phenomena. For example, the characteristics of metal undergoing corrosion can be seen directly from the change in its color, but the process of the change cannot be seen immediately (sub-microscopic). Sub microscopic representation can use with the help of visualization technology. The experimental group in studying electrochemical concepts with multiple representations has an impact on being able to understand the direction of electron movement in galvanic cells, corrosion processes, batteries, electrolytic cells, and electroplating.

In connection with the findings in answering the second hypothesis, no effect was found between learning styles on conceptual understanding. Based on the results of the questionnaire distribution of learning styles, it is seen that visual learning styles are more dominant than verbal. Still, these results do not contribute to increasing conceptual understanding. This result is supported by several findings from the results of the study (Garner-O'Neale & Harrison, 2013; Kidanemariam, Atagana, & Engida, 2014) concluded that learning styles do not contribute to improving the academic achievement of chemistry students, fundamental understanding concepts and learning outcomes. The same results, that interaction between learning style and academic achievement was not significant and did not affect academic achievement (Sahin, 2010). Learning styles relate to each individual's way of receiving new information. In the context of this study, there are indications that the strategies implemented can accommodate how students obtain new information in improving the understanding of concepts. Although learning styles do not have a direct effect, learning styles possessed by students in learning are essential to consider.

4. CONCLUSIONS:

Based on the findings in this study, it can be concluded that the PBL strategy could enhance the students' understanding of the concept in chemistry. However, PBL strategies that apply with multiple representations show significantly better results compared to those without multiple representations. Besides, students' learning style does not directly influence the improvement of students' understanding of concepts. So that, the support of Multiple Representations in Project-Based Learning strategies can effectively enhance students' understanding of concepts in chemistry regardless of their learning style.

It is envisaged that this study might contribute to the research in instructional strategies, especially in the area of chemistry teaching, by providing two leading suggestions. First, the chemistry teacher may apply the PBL strategies with MR to improve students' conceptual understanding without worrying about students' input preferences. Second, other researchers should corroborate this study in other contexts and might ensure the effectiveness of PBL with MR by considering the different dimensions of students' learning preferences

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Table 1. *The Content of Problem Scenario in Worksheet*

Problem Scenario	Description	Target Concept
The battery energy source never separated from our lives	Energy changes in batteries, electrodes, types of batteries, charge and discharge processes	Oxidation-reduction reactions, galvanic cell, battery
Fuel cell breakthrough environmentally friendly vehicles	Electrodes in fuel cells, energy changes, the formation of water as emission	Oxidation-reduction reactions, galvanic Cell, Fuel cell
The phenomenon of the impact of corrosion on metal materials	Corrosion as the cause of the collapse of a bridge. Corrosion prevention methods	Oxidation-reduction reactions, galvanic cell, Potential standard, corrosion

Electroplating technology	The principle of electroplating Electroplating used in to prevent corrosion, and Electrodes	Oxidation-reduction reactions, electrolytic cell, energy change

Table 2. *The Implementation PBL Strategy in Control Group & Experimental Group*

PBL Steps	**Control Group** (without Multiple Representations)	**Experimental Group** (with Multiple Representations)
Step 1. Orienting students to problems.	The instructor explains the PBL strategy process in learning, including the role of students and tutors. The instructor explains the instructional objective of the electrochemical — division of groups, then the distribution of worksheets for each group member.	The instructor explains the PBL strategy process in learning, including the role of students and tutors. The instructor explains the instructional objectives of the electrochemical subject matter, which include macroscopic, submicroscopic, and symbolic aspects. Students are divided into four groups, and then the worksheet is distributed to each individual.
Step 2. *Organizing learners to learn.*	Students brainstorm and play an active role in group discussions to identify problems from the four problem scenarios given.	students brainstorm and play an active role in group discussions to identify problems from the four problem scenarios given
Step 3. *Assisting independent and group investigation.*	Each student in the group must be active in the discussion and work together in investigation to construct new knowledge about galvanic cells, batteries, energy changes in galvanic cells, fuel cells, corrosion and electroplating from various learning sources as a solution to problem-solving and to answer the questions on the worksheet.	Each student in the group must be active in the discussion and work together in the investigation to construct new knowledge, about the concept of galvanic cells, batteries, energy changes, fuel cells, corrosion and electroplating which contains macroscopic, submicroscopic and symbolic aspects. Information collected from various learning sources as a solution in problem-solving and to answer the questions on the worksheet
Step 4. *Developing and presenting artefacts and exhibits.*	Each group prepares a report of results based on information collected as a solution in solving problems through presentations and posters.	Each group prepares a report of results based on information collected as a solution in solving problems through presentations and posters.
Step 5. *Analyzing and evaluating the problem-solving process.*	Students reconstruct their thoughts and activities during various phases of the lesson, how they get a clear understanding of the problem situation, and find solutions to solve problems together in groups	Students reconstruct their thoughts and activities during various phases of the lesson, how they get a clear understanding of the problem situation associated with electrochemical concepts with explanations containing aspects of the macroscopic level, submicroscopic level, and symbolic

	levels and find solutions to solve problems together in groups

Table 4. *Descriptive Statistics Pre-test and Post-test Score*

Groups	**Learning Style**	**Mean**		**Std. Deviation**		**N**
		Pre-test	**Post-test**	**Pre-test**	**Post-test**	
Control Group	Verbal	33.692	61.077	3.859	10.828	13
	Visual	35.267	60.667	7.111	10.888	45
	Total	34.913	60.759	6.527	10.781	58
Experimental Group	Verbal	35.750	74.312	5.222	10.222	16
	Visual	34.674	74.860	6.432	8.757	43
	Total	34.966	74.711	6.102	9.088	59
Total	Verbal	34.828	68.379	4.698	12.292	29
	Visual	34.977	67.602	6.755	12.161	88
	Total	34.940	67.795	6.289	12.145	117

Table 5. *Results of ANCOVA Test for The Influence between Variables*

Source	**Dependent Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	Pre-test	. 592[a]	2	.296	.007	.993
	Post-test	5694.588[b]	2	2847.294	28.432	.000
Intercept	Pre-test	106146.916	1	106146.916	2637.484	.000
	Post-test	399503.153	1	399503.153	3989.261	.000
PBL	Pre-test	.103	1	.103	.003	.960
	Post-test	5681.418	1	5681.418	56.732	.000
Learning styles	Pre-test	.512	1	.512	.013	.910
	Post-test	.233	1	.233	.002	.962
Error	Pre-test	4587.989	114	40.246		
	Post-test	11416.489	114	100.145		
Total	Pre-test	147424.000	117			
	post-test	554860.000	117			

a. R Squared =. 000 (Adjusted R Squared =-. 017)
b. R Squared =. 333 (Adjusted R Squared =. 321)

APPENDIX 1.

MULTIPLE CHOICE TESTS

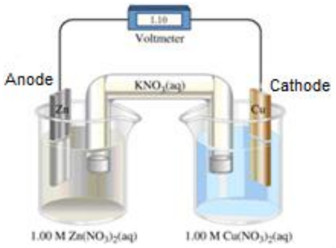
UNDERSTANDING OF CONCEPT OF ELECTROCHEMISTRY

Directions:

1. Read each question carefully and circle one the best answer.

2. Allocation of time available to take the test is 60 minutes

Take a look at the Galvanic cell series below. The picture is related to several questions.



1. When the Galvanic cell is working..
   a. Chemical energy from reactions in cells converted into electrical energy
   b. Chemical energy from reactions in cells converted into heat energy
   c. Electrical energy from reactions in cells converted into chemical energy
   d. The electrical energy from reactions in cells converted to heat energy

2. Galvanic cells equipped with electrodes. The electrodes are ...
   a. Semiconductor dipped in an electrolyte solution
   b. The conductor dipped in an electrolyte solution
   c. Semiconductor dipped in an acidic or basic solution
   d. A conductor dipped in an acid or base solution

3. When Galvanic cells work, redox reactions occur ..
   a. In the electrolyte solution
   b. On the inside of the electrode
   c. On the surface of the electrode
   d. In the electrolyte solution and inside the electrode

4. Read the following statements:
   i. The anode is a negative pole (-) and where the oxidation reaction takes place
   ii. The anode is a positive pole (+) and where the oxidation reaction takes place
   iii. The cathode is the negative pole (-) and the place of the reduction reaction
   iv. The cathode is the positive pole (+) and where the reduction reaction takes place
   The correct statement is:
   a. i and iii
   b. i and iv
   c. ii and iii

d. iii

5. Galvanic cells consist of two half cells. Half the cell is:
   a. Where oxidation and reduction reactions occur in one place
   b. Where oxidation or reduction reactions take place separately and not at the same time
   c. Where oxidation or reduction reactions take place separately and at the same time.
   d. The oxidation or reduction reactions take place separately to form positive and negative ions which dissolve in the electrolyte solution

6. When the Galvanic cell works:
   a. The cation from the salt bridge moves to the cathode, while the anion moves to the anode
   b. The anion from the salt bridge moves to the cathode, while the anion moves to the anode
   c. Both cations and anions can move to the cathode or anode
   d. The cations and anions of the salt bridge remain in the salt bridge

7. The movement of electrons when Galvanic cells work from..
   a. Anode to the cathode through the salt bridge
   b. Cathode to the anode through the salt bridge
   c. The anode to the cathode through the conducting wire.
   d. Cathode to the anode through the conducting wire

8. When the Galvanic cell is working..
   a. Cu reduced to $Cu^{2+;}$ Zn oxidized to Zn^{2+}
   b. Cu^{2+} oxidized to Cu; Zn^{2+} reduced to Zn
   c. Zn^{2+} reduced to Zn; Cu oxidized to Cu^{2+}
   d. Cu^{2+} reduced to Cu; Zn reduced to Zn^{2+}

9. Dry cell batteries are so-called because..
   a. The used electrolyte is completely dry
   b. The used electrolyte is a moist paste
   c. It is using dry electrodes
   d. None of the above

10. Which of the following statement is correct..
    a. The capacity of a cell measured in volts
    b. Primary cells convert electrical energy into chemical energy
    c. Galvanizing of ferrous metals can prevent corrosion
    d. Positive electrodes are called cathodes

11. Which of the following batteries commonly used at electric power stations?
    a. Zink-Carbon Battery
    b. Nickel-Cadmium Battery
    c. Lead-acid battery
    d. Lithium battery

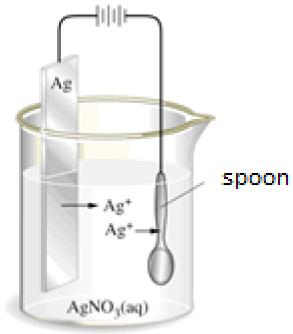
12. Fuel cells used to convert chemical energy into..
    a. Electricity energy
    b. Mechanical energy
    c. Electricity energy
    d. Potential energy

13. Choose the wrong statement from the following options..
    a. Fuel cell emission levels are far below the permitted limit
    b. Fuel cells have a high level of noise
    c. Fuel cells have high-efficiency

d. Fuel cells are modular

14. The change that happened during the process of charging the battery is ..
    a. Chemical energy becomes heat energy
    b. Electrical energy becomes chemical energy
    c. Chemical energy becomes electrical energy
    d. Chemical energy becomes chemical energy

The picture is related to several questions below



15. What is the energy conversion that occurred in the cell above ....
    a. Chemical energy becomes heat energy
    b. Heat energy becomes electrical energy
    c. Electrical energy becomes chemical energy
    d. Electrical energy becomes heat energy

16. The occurrence of the electroplating process is marked by..
    a. Electrons move from the anode to the cathode
    b. Electrons move from the cathode to the anode
    c. Coating occurs at the anode
    d. Anode mass increases

17. In the cell above, what acts as a cathode ..
    a. Ag
    b. Pt
    c. Spoon
    d. Cu

18. During the reaction in the electrolytic cell ...
    a. Oxidation occurs at the anode
    b. Oxidation occurs at the cathode
    c. Reduction occurs at the anode
    d. Reduction occurs in the conducting wire

19. Electroplating is an example of the application of electrochemical cells from ......
    a. Electrolytic cell
    b. Galvanic Cells
    c. Voltaic Cell
    d. Fuel cell

20. The functions of electroplating include, except..
    a. Aesthetics
    b. Harden metal surfaces
    c. Protect metal from corrosion
    d. Increase corrosion rate

21. In electrolytic cells, chemical reactions take place .....
    a. Spontaneously
    b. Not spontaneously
    c. Back and forth
    d. Out of circuit

22. The difference between galvanic cells and electrolytic cells is
    a. Both occur spontaneously
    b. In a galvanic cell, electrical energy is converted into chemical energy; in electrolytic cells, chemical energy is transformed into electrical energy
    c. In electrolytic cells, electrical energy is converted into chemical energy on galvanic cells, and chemical energy is transformed into electricity
    d. Galvanic cells require an external current

23. Factors affecting the rate of corrosion in metals include, except..
    a. Temperature
    b. pH
    c. Concentration
    d. Bond

24. The battery that is classified as a secondary cell is ...
    a. Silver oxide battery
    b. Mercury oxide batteries
    c. Lead-acid battery
    d. Zinc-carbon battery

25. The change happened during the process of discharging the battery is...
    a. Chemical energy becomes heat energy
    b. Electrical energy becomes chemical energy
    c. Chemical energy becomes electrical energy
    d. Chemical energy becomes chemical energy

APPENDIX 2.

Visual/Verbal Learning Style Questionnaire

This questionnaire is designed to find out what you learning preferences are; (Verbal/Visual).

Direction:

1. This questionnaire is consisted of 11 questions and should be done in 15 minutes.
2. Read each of the question carefuly and please put a cross (X) on ‘a’ or ‘b’ to indicate your answer.

1. When I think about what I did yesterday, I am most likely to get
    a. picture.
    b. words.
2. I prefer to get new information in
    a. pictures, diagrams, graphs, or maps.
    b. written directions or verbal information.
3. In a book with lots of pictures and charts, I am likely to

a. look over the pictures and charts carefully.

b. focus on the written text.

4. I like teachers

a. who put a lot of diagrams on the board.

b. who spend a lot of time explaining.

5. I remember best

a. what I see.

b. what I hear.

6. When I get directions to a new place, I prefer

a. a map.

b. written instructions.

7. When I see a diagram or sketch in class, I am most likely to remember

a. the picture.

b. what the instructor said about it.

8. When someone is showing me data, I prefer

a. charts or graphs.

b. text summarizing the results.

9. When I meet people at a party, I am more likely to remember

a. what they looked like.

b. what they said about themselves

10. For entertainment, I would rather

a. watch television.

b. read a book.

11. I tend to picture places I have been

a. easily and fairly accurately.

b. with difficulty and without much detail.

Adopted from:
North Carolina State University, Felder, R.M., Soloman, B.A. (2020) Index of Learning Styles Questionnaire. *Learning Styles and Index of Learning Styles*. Retrieved from https://www.webtools.ncsu.edu/learningstyles/