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Development of the Ethnochemistry Magazine Using Traditional Gold Mining Culture and Gold Crafts

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Abstract: Research and development were conducted with the aim of describing the chemistry concepts contained in the traditional gold mining culture in Prabu village, Middle Lombok and gold crafts in Sekarbela, Mataram. This research is a qualitative descriptive study with a survey approach, conducted in collaboration with 4D Research and Development. The data in this study were collected using the triangulation method, which included interviews, observations, and literature studies. The data analysis technique employed the Miles and Huberman method, which involved data reduction, data presentation, and drawing conclusions. The results of the study indicate that in the traditional gold mining culture in Prabu Village, Middle Lombok, and the gold craft cultural activities in Sekarbela Mataram, there are chemical concepts, including elemental chemistry, reaction equations, oxidation-reduction reactions, the application of the solubility product of salts to separate chemical components from their mixtures, the concept of acids and bases, and the concept of colloids. Teaching materials in the form of ethnochemistry magazines from research and development have a feasibility category that is very feasible, based on the magazine's size, cover design, and content design, with an average V coefficient of 0.94. The feasibility of ethnochemistry magazines, based on the material component indicator, with sub-indicators of material suitability and stimulating curiosity, as well as the feasibility of presentation, with sub-indicators of presentation techniques and presentation support, and the linguistic component indicator, is classified as very feasible, with an average V coefficient of 0.93. In general, ethnochemistry magazines from research and development are classified as very feasible, with an average V coefficient of all aspects of 0.935.

Keywords: Gold Crafts; Ethnochemistry Magazine; Traditional Gold Mining Culture.

Introduction

Teaching materials are a set of materials arranged systematically, both written and unwritten, so as to create an environment or atmosphere that allows students to learn [1]. Teaching materials refer to all forms of resources used by teachers or instructors to facilitate teaching and learning activities in the classroom [2]. Meanwhile, teaching materials as all forms of materials or materials arranged systematically that are used to help teachers or instructors carry out teaching and learning activities, thereby creating an environment or atmosphere that facilitates student learning [3]. Based on this definition, teaching materials, as one component of learning, are among the factors that contribute to achieving learning objectives. Therefore, in carrying out learning, it is necessary to have adequate teaching materials available. One type of teaching material that can be used in the learning process, especially in chemistry learning, is a chemistry magazine.

The content and its presentation in teaching materials need to be carefully considered to increase student interest, motivation, and ease of understanding. One way to meet these expectations is to present material that relates to students' environments and daily lives. Teaching materials with content relevant to students' environments can be a valuable learning resource for contextual or constructivist learning, both innovative approaches to education.

When designing teaching materials that demonstrate a connection to the environment, local culture can serve as a valuable source. Every region has its own culture, which contains the concepts taught in schools. Chemistry learning that connects to local culture is called ethnochemistry. Ethnochemistry is a part of ethnoscience. Ethnoscience has advantages, including [4]: 1) As an innovative learning method that is not just about conveying information (transfer of information) but the construction of knowledge (construction of knowledge) by students through learning and working in groups, 2) Students gain an integrated understanding of the fields of science and culture in solving various problems in a cultural context, and have the ability to make valid decisions based on scientific principles, 3) Has a positive impact on learning because students actively participate in the learning process, 4) Students feel happy to learn chemistry because they see a connection between concepts or principles in chemistry and their culture. Ethnochemistry can be utilised as an educational tool to enhance awareness and understanding of the significance of local culture [5]. According to various studies, the application of ethnochemistry in learning through the use of culture yields positive results in cognitive, affective, and psychomotor learning outcomes [6].

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In the Lombok region, there are various cultures that have the potential to be used as sources of material for ethnochemical-based teaching materials, including traditional gold mining in Prabu Village, Central Lombok, and gold jewellery crafts in Sekarbela, Mataram, whose processes are linked to chemical concepts such as those in the Basic Chemistry course. To the author's knowledge, no research has been conducted on these two cultures to identify the chemical concepts they contain, which could determine their potential as sources of teaching materials.

The objectives of this study are 1) to describe the chemical concepts contained in the traditional gold mining culture in Prabu village, Central Lombok, and gold crafts in Sekarbela, Mataram, which can be used as a source for developing ethnochemical-based teaching materials, and 2) to develop teaching materials in the form of ethnochemical magazines using traditional gold mining in Prabu village and gold crafts in Sekarbela as source materials.

Research Method

This research uses 2 approaches, namely a naturalistic/qualitative approach with an ethnographic research type for describe the chemical concepts contained in the traditional gold mining culture in Prabu village, Central Lombok, and gold crafts in Sekarbela Mataram, and development research to develop teaching materials in the form of ethnochemical magazines using chemical content contained in the traditional gold mining process in Prabu village and gold crafts in Sekarbela as source material.

The use of a naturalistic approach is based on holistic or comprehensive considerations of the sources and types of data to be collected. Furthermore, naturalistic research is based on the overall social and environmental situation being studied. The research stages of ethnography consist of description, analysis, and interpretation. The description stage is conducted to explore the background of the problem through initial observations related to the research object. The analysis stage is conducted to obtain accurate data based on the problem formulation and research objectives, thereby answering the research questions that have been formulated. The interpretation stage is conducted to obtain accurate conclusions based on the data analysis that has been conducted.

The data in this study include 1) mining process data with data sources from 3 gold miners in Prabu village, 2) gold craft process data sourced from 3 gold craftsmen in Sekarbela, and 3) validity data from the development of chemical magazines with data sources from 3 lecturers of the Chemistry Education Study Program, FKIP, Mataram University.

The data collection techniques employed in this study included observation, interviews, and documentation to gather data related to the mining process and traditional gold crafts. The use of these techniques was based on the type of data collected. In analyzing the data, the researcher used a combined qualitative data analysis technique of the Miles & Huberman and Spradley models. The use of these techniques was based on their suitability to the type of data to be analyzed, namely, data collected using observation, interviews, and documentation techniques. The data analysis technique model [8] comprises three stages: data reduction, data presentation, and conclusions or verification. In this data reduction stage, the researcher selected, simplified, or sorted the raw data that had been collected or recorded in the observation and interview sheets, while simultaneously discarding unnecessary data. The data was then sorted and grouped according to type. After the data was reduced, the researcher then arranged the data into a systematic arrangement and then analyzed it by consulting with relevant theories and previous research results. After the process was completed, the researcher drew conclusions from the data analysis results, which also addressed the research problem formulation. This activity was carried out by researchers continuously after each observation. Validity data for the developed magazine was collected using a questionnaire using a Likert scale.

The validity analysis of the developed magazine employs the formula [9], which is as follows: The data analysis technique used in this study is Aiken's V index, used to calculate the content validity coefficient based on the expert panel's assessment of each item [10]. The Aiken's V formula is as follows.

$$v = \frac{\sum s}{n(s-1)}$$

Information:
s = r-lo
lo = lowest validity assessment number
c = highest validity assessment number
r = number given by the assessor
n = number of validators
The validation results were analyzed using the validity criteria of Aiken's V index, as outlined in Table 1.

Table 1. Validity and Feasibility Categories Based on Aiken's V Index

Aiken's Index	Validity	Qualifications
$0.4 < V$	Low	Not enough
$0.4 \leq V \leq 0.8$	High	Eligible
$V > 0.8$	Very high	Very Worthy

Results and Discussion

Leaching Process and Related Chemistry Science Content

In the traditional gold mining process in Prabu village, Central Lombok, one of the stages is leaching, a process carried out on ore containing metal with chemicals to convert the valuable metals into a soluble form, such as a salt [11-12]. The leaching process employed by the Gunung Prabu gold miners utilises the hydrometallurgical method, a technique that involves chemical reactions in aqueous solutions to extract metal from its source. In this process, the sieved material is placed in a tarpaulin-lined pool, then doused and soaked in water filled with chemicals such as potassium cyanide, hydrogen peroxide, and lime, so that the gold in the rock or soil dissolves [13].

Hydrogen peroxide is a chemical compound with the formula H_2O_2. In its pure form, it is a clear, pale blue fluid. Hydrogen peroxide is unstable and decomposes slowly upon exposure to light, releasing water and oxygen as a result. According to the following reaction equation:

$2\ H_2O_2 \rightarrow 2\ H_2O + O_2$

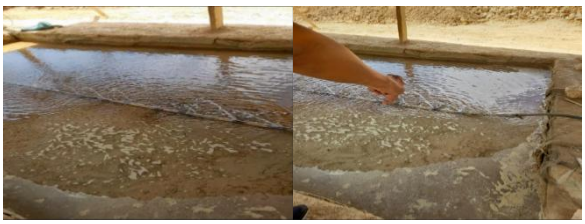

Figure 1. Gold Leaching in Ponds Source: Personal Documentation

Based on the reaction above, hydrogen peroxide can function as an oxygen source in leaching processes that require oxygen. The type of reaction that occurs in the decomposition of hydrogen peroxide is: oxidation-reduction (redox) reaction [14]. The redox concept includes:
1. Based on oxygen involvement. Reduction is a reaction that releases oxygen from a substance, while an oxidation reaction is a reaction that binds oxygen to a substance.
2. Based on electron transfer. A reduction reaction is a reaction that binds electrons, while oxidation is a reaction that releases electrons from a substance.
3. Based on changes in oxidation number. The oxidation number is a number that indicates the number of electrons an atom releases or receives in the process of forming a compound. A reduction reaction is a reaction that causes a decrease in the oxidation number, while oxidation is a reaction that causes an increase in the oxidation number of a substance.

In the decomposition of hydrogen peroxide into water and oxygen, the oxidation number of the oxygen atom in H_2O_2 is -1. The oxidation number of oxygen in H_2O as one of the reaction products -2, which means that a reduction reaction occurs in the reaction. The oxidation number of oxygen in $O_2$is 0, which means that oxidation occurs in this reaction. Because H_2O_2 undergoes both reduction and oxidation simultaneously during decomposition, the reaction is classified as a disproportionation reaction.

In the leaching process, the first reaction that occurs is the decomposition of hydrogen peroxide. The oxygen produced in this decomposition then reacts with the gold element to form Au^{3+} cations. In this reaction, gold, with a charge of 0, changes to 3+ by releasing 3 electrons, so the reaction is oxidation. In this reaction, the oxygen comes from hydrogen peroxide, so it is hydrogen peroxide that oxidizes the gold. Substances that oxidize other substances are called oxidizing agents.

Potassium cyanide is a chemical substance with the chemical formula KCN. In aqueous solution, KCN can dissociate to form K^+ ions and the anion CN^-. In the leaching process, this ion binds to gold cations (Au^{3+}), the result of gold (Au) oxidation [15]. The bond between the two ions forms a complex compound that dissolves in water. The reaction that occurs is:

$KCN_{(aq)} \rightarrow K^+_{(aq)} + (CN)^-_{(aq)}$
$(CN)^-_{(aq)} + Au^{3+}_{(aq)} \rightarrow Au(CN)_2^-{}_{(aq)}$

$Au(CN)_2^-{}_{(aq)}$ is a complex ion with Au^{3+} ions as the central atom and $(CN)^-$ as ligands. Ligands are atoms, ions, or molecules that can donate one or more electron pairs to form coordinate covalent bonds with a central atom or ion.

The lime used in gold mining is quicklime, a substance with the chemical formula CaO. This lime reacts with water to form $Ca(OH)_2$ (calcium hydroxide), a basic compound. The reaction follows the following equation:

$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)}$

In water, calcium hydroxide can produce hydroxide ions, OH^-, which can bind H+ ions to form H_2O_2.

Based on the characteristics of the chemical materials used in the leaching process, the chemical processes that occur can be explained according to the following reaction equation [16].
$H_2O_2 \rightarrow H_2O + O_2$
$4\ Au + 8\ KCN^- + O_2 + 2\ H_2O \rightarrow 4\ Au(CN)_2^- + 4\ KOH$

Based on reaction 1) hydrogen peroxide functions as an oxygen source that oxidizes gold so that it can dissolve. Therefore, hydrogen peroxide acts as an oxidising agent in this process.

Ion $(CN)^-$ can also bind with H^+ ions to form HCN (hydrocyanic acid). Therefore, a high concentration of H^+ ions or a low pH facilitates the formation of HCN. Hydrocyanic acid is a colorless liquid compound and is very toxic, with a boiling point of 25.6°C. In addition, cyanide in the form of cyanide acid cannot leach gold [17]. Therefore, in the leaching process, the formation of HCN needs to be avoided by regulating the conditions in a basic or high pH atmosphere.

In the leaching process, HCN formation is prevented by binding H+ ions through the reaction with OH- ions sourced from the added lime. Thus, the addition of lime in the leaching process serves to raise the pH and increase OH- ions, which can bind H+ ions, thereby preventing HCN formation and protecting workers from poisoning. Typically, the pH is set in the range of 10 - 10.5. If the pH is below 10, the cyanide will evaporate into dangerous cyanide gas.

Gold Refining Process and Related Chemical Content

The gold refining process, from gold mining in Prabu Village, and the extraction of silver from gold that still contains silver and copper impurities, are carried out by gold craftsmen in Sekarbela.

Copper is a chemical element with the symbol Cu (cuprum) and atomic number 29. The characteristics of copper metal are:
1. It is soft, malleable, and reddish-orange in color with a bright metallic luster.
2. It is malleable, ductile, and an excellent conductor of heat and electricity. Only silver has a higher electrical conductivity than copper.
3. The surface of copper exposed to air gradually turns a dull, brownish color.
Copper can be combined with other metals to form alloys. Some copper alloys include brass, an alloy of copper and zinc; bronze, an alloy of copper and tin; and cupronickel, an alloy of copper and nickel.

Silver is a metal with the atomic number 47 with the symbol Ag (Argentum). The silver includes transition metals, soft, white, and shiny, and has electrical conductivity, thermal conductivity, and reflectivity. It is the highest of all metals. It occurs naturally in pure, free

form (native silver), as alloys with gold and other metals, and in minerals such as argentite and chlorargyrite.

Silver has several uses, including as a form of money, in solar panels, water filtration, jewellery, ornaments, high-value tableware and furniture, as an industrial material in sockets and conductors, in speciality mirrors, window coatings, and in catalytic chemical reactions. The compound is used in photographic film and for X-ray imaging.

Silver nitrate. Dilute silver and other silver compounds are used as disinfectants and microbicides (oligodynamic effects), added to bandages and wound dressings, catheters, and other medical equipment.

To separate gold from its impurities, hard water is used. One example of hard water is nitric acid (HNO_3). In this process, gold reacts, while silver and copper react to produce substances in dissolved form according to the following reaction equation:

$$Cu_{(s)} + 2\,HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + NO_{2(g)} + H_2O_{(l)}$$
$$Ag_{(s)} + 2\,HNO_{3(aq)} \rightarrow AgNO_{3(aq)} + NO_{2(g)} + H_2O_{(l)}$$

The gold that does not dissolve is separated from the liquid/solution, and then table salt is added. Salt is a substance used as a flavouring agent in food, containing mainly sodium chloride with the chemical formula NaCl. In salt water, it can dissociate to produce sodium ions (Na^+) and chloride (Cl^-).

$$NaCl_{(s)} + H_2O \rightarrow Na^+_{(qa)} + Cl^-_{(aq)}$$

Ion Cl^- can bind with Ag^+ to form silver chloride (AgCl) in the form of a white solid (in the reaction process forms a precipitate) according to the reaction equation:

$$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$$

Ion Cl^- from table salt with Cu ions^{2+}cannot form deposits (Cu^{2+}remains in dissolved form). This is due to the difference in K_{sp}or the solubility between AgCl and $CuCl_2$, in this case the solubility of $CuCl_2$ ($K_{sp} = 1{,}72 \times 10^{-7}$) is greater than the solubility of AgCl ($K_{sp} = 1{,}8 \times 10^{-10}$). Thus, adding table salt to a mixture of copper and silver solutions causes the copper and silver to separate.

In the process of extracting silver from silver chloride deposits, and AgCl precipitate after being separated from the blue liquid is added with battery acid containing sulfuric acid (H_2SO_4), hot water and zinc. In this process, the precipitate initially dissolves to form Ag_2SO_4dissolved. The solubility of Ag2SO4 is relatively high, specifically 1.4×10^{-5}.

$$AgCl_{2(s)} + H_2SO_{4(aq)} \rightarrow Ag+_{(aq)} + SO_4^{2-}{}_{(aq)} + 2\,HCl_{(aq)}$$

Furthermore, in the presence of zinc (Zn), silver ions transform into solid silver metal, while zinc metal dissolves and forms Zn^{2+} ions. In this process, a reaction occurs according to the reaction equation:

$$2\,Ag^+_{(aq)} + Zn_{(s)} \rightarrow Ag_{(s)} + Zn^{2+}_{(aq)}$$

Based on the reaction above, Ag ions$^+$ are reduced by Zn. This reaction can occur because silver is more easily reduced than zinc due to the reduction potential of Ag^+, +0.7996 V, which is greater than that of Zn2+, -0.7618 V. In the Volta series, zinc metal is located on the left, while silver metal is on the right. In the displacement reaction, the free metal on the left of the Volta series is able to displace or reduce the metal on the right.

Gold Craft Washing Process and Related Chemical Science Content

In the washing process for gold crafts, a mixture of alum, saltpeter, table salt and soap nuts is used.

Alum or kalium aluminium sulfate with the chemical formula $KAl(SO_4)_2$, commonly found as dodecahydrate, $Cal(SO_4)_2 \cdot 12H_2O$. Alum is easily soluble in water. In an aqueous solution, alum particles have a neutral electrical charge, allowing them to attract colloidal particles with different electrical charges. This property is applied to the use of alum as a purifier, for example, in water purification. In water purification with alum, colloidal particles dispersed in water combine with alum particles to form a heavier precipitate. The formed alum precipitate will help absorb, capture, and separate water and dirt particles. This process is known as adhesion and absorption carried out by alum colloidal particles. This makes alum very effective as a purifier.

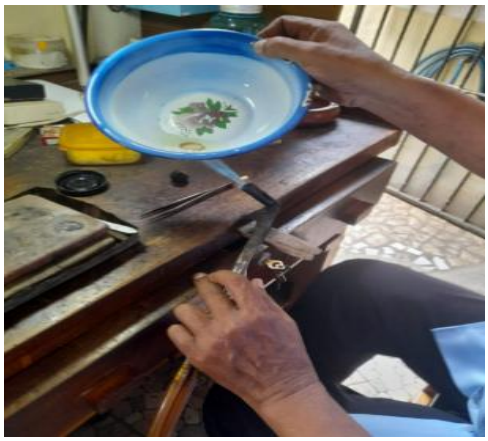

Figure 2. Washing Process

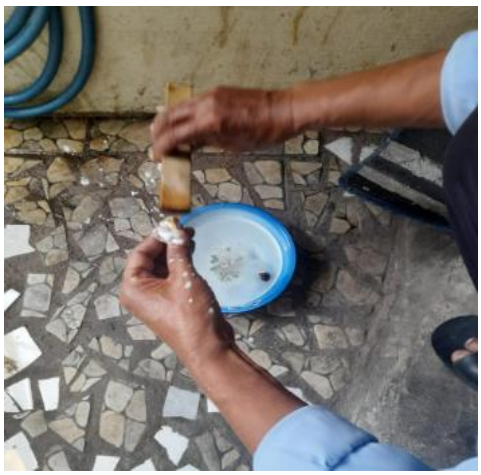

Figure 3. Brushing Process

Burp is a chemical with the formula KNO_3. One of the properties of KNO_3 is that it is able to oxidize other substances, so in this process, the use of KNO_3 is

important to oxidize the remaining dirt so that the craft results look better.

Salt is a substance containing positive base ions and negative acid ions resulting from the reaction between an acid and a base. The salt used in the goldsmithing process has aberrant properties, allowing it to remove stains and dirt.

Soap Nuts (especially *Sapindus rarak*, also known as *S. mucorossi*) or also known as rerek or lamuran, is a plant known for its seeds, which are used as a detergent traditionally. The part of soapberries that has soap-like properties is saponin. Saponin is a strong surfactant that can cause foaming when rubbed or mixed with water.

Chemical Magazine Development Results

The teaching materials developed from the results of this research are in the form of an ethnochemical magazine. The feasibility is based on the validity of the magazine design, using indicators such as magazine size, cover design, and content design [19-20]. The V coefficients of the three indicators are respectively 1.00, 0.88 and 0.92, all of which are categorized as very feasible. In general, the magazine design is categorized as very feasible with an average V coefficient of 0.94. The feasibility of the magazine content is assessed using indicators of material components, including sub-indicators of material suitability and stimulating curiosity, as well as presentation feasibility with sub-indicators of presentation techniques and presentation support, and linguistic component indicators. The feasibility of the magazine content is generally very feasible, with an average V coefficient of 0.93. Based on the sub-indicators, all sub-indicators have been categorized as very feasible with a V coefficient, namely the sub-indicator of material suitability 1.00, stimulating curiosity 0.88, presentation techniques 0.94 and linguistic components 0.92. In general, the feasibility of the ethnochemical magazine, resulting from research and development, is classified as very good, with an average V coefficient across all aspects of 0.935.

Here are some examples of pages from the developed magazine as follows.

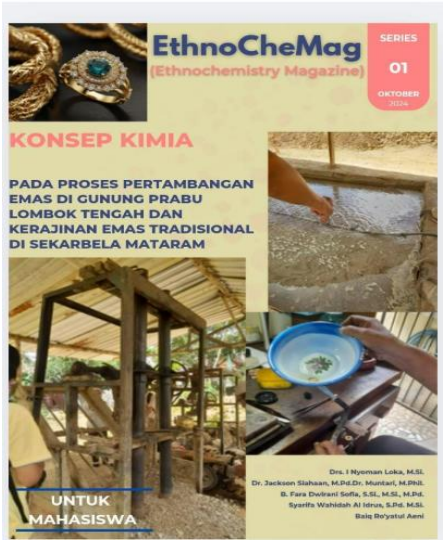

Figure 4. Magazine Cover View

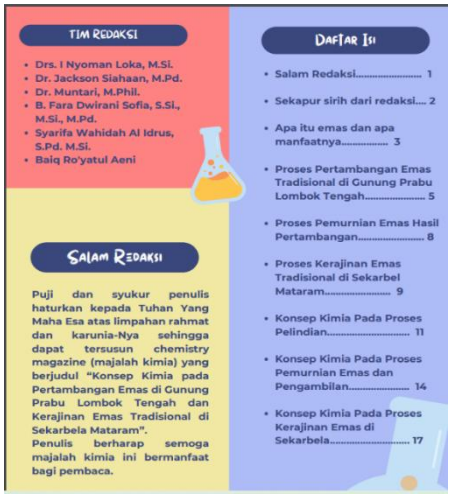

Figure 5. Table of Contents View

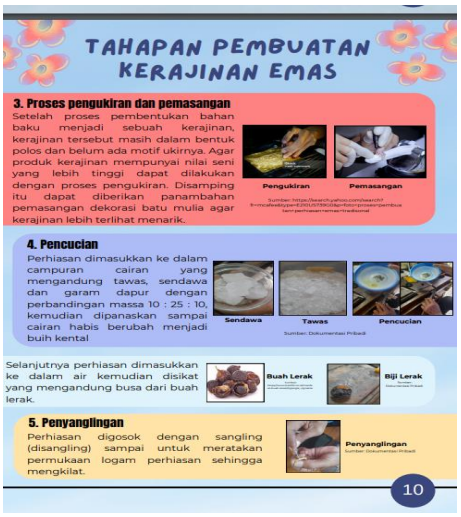

Figure 6. Magazine Contents Display

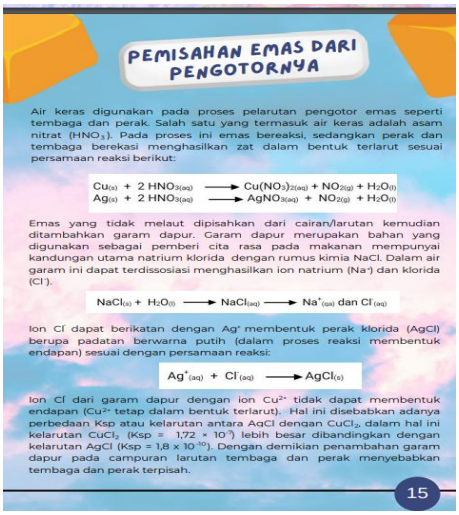

Figure 7. Magazine Contents Display

Conclusion

Based on the research results, it can be concluded is in the traditional gold mining culture in Prabu Village, Central Lombok and the gold craft cultural activities in

Sekarbela Mataram, there are chemical concepts, including elemental chemistry, reaction equations, oxidation-reduction reactions, the application of the solubility product of salts to separate chemical components from their mixtures, the concept of acids and bases, and the concept of colloids. These concepts are found in the Basic Chemistry course material. In general, the feasibility of ethnochemical journals resulting from research and development is classified as very feasible, with an average V coefficient of 0.935 for all aspects.

Author's Contribution

I. N. Loka: Conceptualization, research design, development of the ethnochemistry magazine, integration of traditional gold mining culture and gold crafts. J. Siahaan: Literature review and contribution to manuscript drafting. Muntari: Validation of ethnochemical concepts. B. F. D. Sofia: Media layout design, visual development. S. W. Al Idrus: Ethnoscience framework analysis. B. R. Aeni: Data collection support.

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References

[1] A. Prastowo, *Panduan Kreatif Membuat Bahan Ajar Inovatif*. Surabaya, Indonesia: Diva Press, 2015.

[2] A. Majid, *Perencanaan Pembelajaran: Mengembangkan Standar Kompetensi Guru*. Bandung, Indonesia: PT Remaja Rosdakarya, 2013.

[3] Hamdani, *Strategi Belajar Mengajar*. Bandung, Indonesia: Pustaka Setia, 2011.

[4] M. Imansari, S. Sudarmin, and W. Sumarni, "Analisis literasi kimia peserta didik melalui pembelajaran inkuiri terbimbing bermuatan etnosains," *Jurnal Inovasi Pendidikan Kimia*, vol. 12, no. 2, 2018.

[5] Y. Andayani, A. A. Purwoko, M. Haris, E. N. Lestari, and B. E. Hurairah, "Peningkatan kemampuan guru kimia dalam mengidentifikasi sains ilmiah dari budaya masyarakat Sasak, Samawa dan Mbojo (Etnosasambo)," *Jurnal Pengabdian Magister Pendidikan IPA*, vol. 6, no. 4, pp. 908–912, 2023.

[6] I. Abramova and A. Greer, "Ethnochemistry and human rights," *Chemistry and Biodiversity*, vol. 10, no. 9, pp. 1724–1728, 2013, doi: 10.1002/cbdv.201300211.

[7] M. Yuniastuti, Miftakhuddin, and M. Khoiron, *Media Pembelajaran untuk Generasi Milenial*. Surabaya, Indonesia: Scopindo Media Pustaka, 2021.

[8] M. B. Miles and A. M. Huberman, *Analisis Data Kualitatif*. Jakarta, Indonesia: Universitas Indonesia Press, 1992.

[9] C. Merino-Soto, "Aiken's V coefficient: Differences in content validity judgments," *MHSalud*, vol. 20, no. 1, pp. 23–32, 2023, doi: 10.15359/mhs.20-1.3.

[10] A. A. P. Antara, *Penyetaraan Vertikal dengan Pendekatan Klasik dan Item Response Theory (Teori dan Aplikasi)*. Yogyakarta, Indonesia: Deepublish, 2020.

[11] X. Li and K. Binnemans, "Oxidative dissolution of metals in organic solvents," *Chemical Reviews*, vol. 121, no. 8, pp. 4506–4530, 2021, doi: 10.1021/acs.chemrev.0c00917.

[12] M. Sethurajan, P. N. Lens, H. A. Horn, L. H. Figueiredo, and E. D. van Hullebusch, "Leaching and recovery of metals," in *Sustainable Heavy Metal Remediation: Volume 2—Case Studies*, Cham, Switzerland: Springer, 2017, pp. 161–206, doi: 10.1007/978-3-319-61146-4_6.

[13] C. Anning, J. Wang, P. Chen, I. Batmunkh, and X. Lyu, "Determination and detoxification of cyanide in gold mine tailings: A review," *Waste Management & Research*, vol. 37, no. 11, pp. 1117–1126, 2019, doi: 10.1177/0734242X19876691.

[14] N. Wang, S. Ma, P. Zuo, J. Duan, and B. Hou, "Recent progress of electrochemical production of hydrogen peroxide by two-electron oxygen reduction reaction," *Advanced Science*, vol. 8, no. 15, Art. no. 2100076, 2021, doi: 10.1002/advs.202100076.

[15] A. Birich, S. Stopic, and B. Friedrich, "Kinetic investigation and dissolution behavior of cyanide alternative gold leaching reagents," *Scientific Reports*, vol. 9, no. 1, Art. no. 7191, 2019, doi: 10.1038/s41598-019-43383-4.

[16] C. F. Pratama, "Pengaruh penambahan H_2O_2 pada sianidasi emas dari batuan mineral," Laporan Penelitian, Jurusan Kimia, Fakultas MIPA, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia, 2011.

[17] J. W. Beay, "Analisa pengolahan bijih emas dengan pelindian sianidasi (leaching) dengan variabel *grind size*, persen solid, dan penambahan *viscosity modifier* (BO 919) di PT Halmahera Minerals," Laporan Penelitian, Jurusan Teknik Pertambangan, Fakultas Teknik, Universitas Muhammadiyah Maluku Utara, Ternate, Indonesia, 2011.

[18] G. Schlamp, "Noble metals and noble metal alloys," in *Springer Handbook of Materials Data*, Cham, Switzerland: Springer, 2018, pp. 339–412, doi: 10.1007/978-3-319-69743-7_14.

[19] A. D. I. Y. O. Roebianto, S. I. Savitri, I. R. F. Aulia, A. R. Suciyana, and L. Mubarokah, "Content validity: Definition and procedure of content validation in psychological research," *Testing, Psychometrics, Methodology in Applied Psychology (TPM)*, vol. 30, no. 1, pp. 5–18, 2023.

[20] H. Aksah, S. U. H. Johar, I. M. Usman, and A. I. Che Ani, "Design and implementation of content validity: Instrument development for evaluating functional building performance," *WSEAS Transactions on Environment and Development*, vol. 17, pp. 973–982, 2021, doi: 10.37394/232015.2021.17.90.