SEARCH: Science Education Research Journal
Volume 5, Issue 1, 2026
E-ISSN: 3032-6435
https://e-jurnal.iainsorong.ac.id/index.php/jaser

Preliminary Development of an Acid-Base Student Worksheet Based on Guided Discovery Learning Integrated with Ethnoscience to Foster Phase F Students' Critical Thinking Skills

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Abstract

Students' difficulties in understanding acid-base concepts and the limited use of teaching materials that facilitate concept discovery and critical thinking (CT) indicate the need for more contextual learning resources. This study aimed to develop a preliminary prototype of an acid-base student worksheet (SW) based on Guided Discovery Learning (GDL) integrated with ethnoscience, designed by incorporating Ennis's critical thinking indicators for Phase F students. The study employed Educational Design Research (EDR) using the Plomp development model and was limited to the preliminary research and prototyping phases. The participants consisted of four chemistry teachers and 60 Phase F students from SMAN 2 Pariaman, SMAN 4 Pariaman, and SMAN 2 Sungai Limau. Data were collected through interviews, questionnaires, literature review, and self-evaluation using interview guidelines, student needs questionnaires, and a self-evaluation checklist. The development process resulted in Prototype II following revisions to Prototype I based on the findings of the self-evaluation. Prototype II integrates Guided Discovery Learning syntax, Minangkabau ethnoscience contexts, and Ennis's critical thinking indicators as the basis for designing systematic learning activities. The resulting Prototype II represents the outcome of the preliminary development phase and is ready for expert validation as the next stage of the development process.

Article History:
Received 06 July 2026
Accepted 20 July 2026

Keyword:
Guided Discovery Learning; Ethnoscience; Student Worksheet; Critical Thinking Skills; Acid-Base.

How to Cite:
Ramadani, P., & Yuhelman, N. (2026). Preliminary Development of an Acid-Base Student Worksheet Based on Guided Discovery Learning Integrated with Ethnoscience to Foster Phase F Students' Critical Thinking Skills. SEARCH: Science Education Research Journal, 5(1), 26–37. https://doi.org/10.47945/search.v5i1.3243

INTRODUCTION

The demands of 21st century education require students to acquire various important competencies, which are generally referred to as the 4Cs: critical thinking, creativity, communication, and collaboration (Thornhill-miller et al., 2023). Among these competencies, critical thinking is considered one of the most fundamental skills in science education, as it enables students to evaluate information, reason based on evidence, and solve scientific problems systematically (Getu et al., 2024). In learning chemistry, critical thinking skills are needed so that students not only understand concepts, but are also able to connect chemical concepts with phenomena in everyday life and apply them to analyze and solve problems scientifically (Purwanto et al., 2022).

However, developing critical thinking remains a challenge in science education. The 2022 Programme for International Student Assessment (PISA) reported that Indonesia achieved a science literacy score of 383, below the OECD average of 485 (OECD, 2023). The findings indicate that many students still experience difficulties in applying scientific knowledge, explaining scientific phenomena, and interpreting scientific evidence. These competencies are closely related to scientific reasoning, which provides an important foundation for the development of CT in chemistry learning.

One chemistry topic that requires critical thinking skills is acids and bases. This topic is characterized by three levels of chemical representation: macroscopic, submicroscopic, and symbolic (Satria et al., 2020). The relationship between these levels of representation is often a challenge for students because the concept of acid-base not only involves observable phenomena, but also processes at the particle level and the use of chemical symbols or equations. The results of the questionnaire analysis given to 60 students at SMAN 2 Pariaman, SMAN 4 Pariaman and SMAN 2 Sungai Limau showed that 79% of students considered the acid-base topic difficult to understand. These difficulties were attributed to challenges in understanding acid-base concepts (60%), calculating pH (65%), and relating the acid-base topic to everyday life (27%). In addition, all students stated that they preferred learning activities that allowed them to discover concepts independently (78.3%), related the topic to everyday life (38.4%) and was able to train critical thinking skills (53%). Students preferred clear and systematic learning steps and those that presented interesting pictures or illustrations.

Interviews with chemistry teachers at SMAN 2 Pariaman, SMAN 4 Pariaman, and SMAN 2 Sungai Limau indicated that acid-base instruction generally relied on lecture and discussion methods with printed textbooks as teaching materials and student worksheets (SW) and PowerPoint presentations as media. These learning resources have not optimally supported students' interest, curiosity, and analytical skills. Therefore, it is necessary to develop teaching materials that can help students understand concepts while simultaneously training their CT skills in more focused manner.

One teaching material that can be developed is the Student Worksheet. Student Worksheet is a teaching material that can facilitate students' active, independent, and systematic learning through structured learning activities (Aqilla & Effendi, 2022). However, the SW used in schools is generally still conventional. This condition means that SW is not yet optimal in training high-level thinking skills, especially critical thinking skills, and has not provided contextual and meaningful learning experiences (Ulfah et al., 2024).

Previous studies have shown that the application of Guided Discovery Learning (GDL) is effective in helping students build concepts through a discovery process that takes place gradually with teacher guidance (Samudera et al., 2022). Implementing GDL has also been proven to improve problem-solving abilities (Zhafransyah & Sari, 2024) and supports the development of critical thinking skills through observing, analyzing, verifying, and drawing conclusions (Respati, 2023). Apart from being applied in the learning process, GDL is also used as a basis for developing teaching materials. According to research by Yani & Yerimadesi, (2023) GDL-based teaching materials integrated with local cultural values demonstrated good validity and practicality. These findings suggest that Guided Discovery Learning provides a strong foundation for developing teaching materials that facilitate systematic concept discovery and foster students' critical thinking skills through meaningful learning experiences (Yerimadesi et al., 2023).

In addition to GD Learning, the integration of ethnoscience into teaching materials has gained increasing attention because it connects scientific concepts with students' everyday experiences and local cultural practices (Aprilia & Salim, 2025). Ethnoscience serves as a bridge between indigenous knowledge and scientific concepts, enabling students to construct scientific understanding through culturally meaningful learning experiences (Atmojo et al., 2025). Accordingly, ethnoscience-based student worksheets utilize local cultural contexts to promote students' active engagement and conceptual understanding (Mahyuny et al., 2022). Previous studies have also reported that ethnoscience-based learning can improve students' conceptual understanding and foster critical thinking skills (Pieter et al., 2025). However, these benefits can only be achieved when local knowledge is scientifically reconstructed before being integrated into science learning. Scientific reconstruction involves systematically interpreting and aligning indigenous knowledge with established scientific concepts, thereby transforming local cultural knowledge into scientifically meaningful learning. Through this process, students are able to connect their cultural experiences with formal chemistry concepts while minimizing potential misconceptions (Anugrah et al., 2025).

Previous studies have demonstrated that Guided Discovery Learning (GDL) effectively facilitates concept discovery and promotes higher-order thinking skills through structured learning activities (Yerimadesi et al., 2023). Although several studies have integrated Guided Discovery Learning with ethnoscience, they have primarily focused on developing learning modules (Yani & Yerimadesi, 2023). Similarly, ethnoscience-based student worksheets have been developed to enhance students' conceptual understanding and engagement (Mahyuny et al., 2022). However, the systematic integration of Guided Discovery Learning syntax and Ennis' critical thinking indicators into ethnoscience-based acid-base student worksheets remains limited.

To address these gaps, this study aimed to develop a preliminary prototype of an acid-base student worksheet that systematically integrates Guided Discovery Learning syntax, Minangkabau ethnoscience, and Ennis' critical thinking indicators into a single instructional design. Theoretically, this study contributes to the integration of Guided Discovery Learning, ethnoscience, and critical thinking in the development of chemistry learning materials. Practically, this study produced Prototype II of an acid-base student worksheet that is ready for expert validation in the subsequent phase of development.

RESEARCH METHODS

This research is a type of Educational Design Research (EDR), which aims to produce and improve educational products through a systematic process of design, development, and evaluation (Mckenney & Reeves, 2020). The EDR approach was chosen because it focuses not only on developing learning products but also on solving learning problems based on real-world needs. This research uses the Plomp development model, which consists of three phases: preliminary research, prototyping, and assessment (Plomp & Nieveen, 2013). However, the present study was limited to the self-evaluation stage of the prototyping phase, resulting in Prototype II.

The subjects of this study consisted of four chemistry teachers and 60 Phase F students from SMAN 2 Pariaman, SMAN 4 Pariaman, and SMAN 2 Sungai Limau. The chemistry teachers participated in interviews to provide information on learning conditions, the use of teaching materials, and the need for SW development, while the students completed a needs analysis questionnaire. The product developed in this study was an acid-base Student Worksheet based on GD Learning integrated with ethnoscience, which was designed based on the findings of the preliminary research phase is presented in Figure 1.

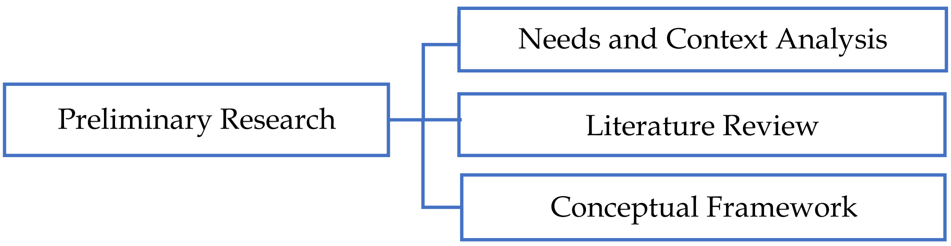


Figure 1. Stages of the Preliminary Research

Needs and Context Analysis

The needs analysis aimed to identify the learning conditions related to the acid-base topic, including the learning process, the teaching materials used, the obstacles encountered, and the needs of teachers and students regarding the development of student worksheets. Context analysis was conducted to examine the findings of the needs analysis, as well as the characteristics of the acid-base topic, learning outcomes, learning objectives, and student characteristics, which served as the basis for product development. Data at this stage were collected through interviews with four chemistry teachers and questionnaires administered to 60 Phase F students from SMAN 2 Pariaman, SMAN 4 Pariaman, and SMAN 2 Sungai Limau. The findings of the needs and context analyses served as the basis for developing Prototype I.

Literature Review

A literature review was conducted to obtain a theoretical basis to support product development. The literature reviewed included the acid-base concept, the Guided Discovery Learning model, ethnoscience, critical thinking skills according to Ennis, the development of student worksheets, and relevant previous research. The results of the literature review were used as a basis for determining the components, content, and characteristics of the developed student worksheets.

Conceptual Framework

The conceptual framework was developed based on the results of the needs and context analyses and supported by a review of relevant literature. It integrates the key concepts that served as the foundation for developing the acid-base student worksheet based on Guided Discovery Learning integrated with ethnoscience. These concepts include the characteristics of the acid-base topic, Guided Discovery Learning syntax, ethnoscience integration, Ennis' critical thinking indicators, and the identified needs of teachers and students for teaching materials. All of these concepts were systematically incorporated into the components and learning activities of the SW to develop Prototype I. The stages of the prototyping phase are presented in Figure 2.

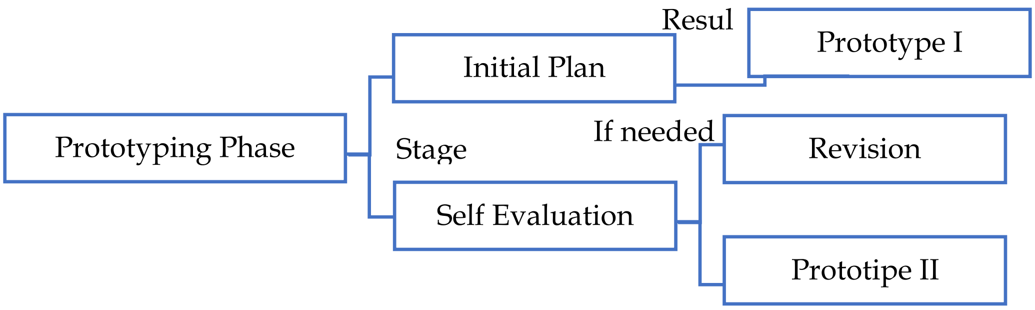


Figure 2. Stages of Prototyping Phase

Initial Plan

The initial design in this study was prepared based on the results of preliminary research that included needs and context analysis, literature review, and conceptual framework. At this stage, Prototype I was designed in the form of an acid-base SW based on Guided Discovery Learning integrated with ethnoscience by integrating material characteristics, Guided Discovery Learning syntax, ethnoscience elements, and critical thinking ability indicators according to Ennis. The resulting Prototype I was then evaluated in the self-evaluation stage.

Self-Evaluation

After Prototype I was developed, the researcher conducted a self-evaluation using a checklist. This evaluation aimed to identify the suitability of each component of the Student Worksheet, including aspects of content, presentation, language, and graphics, as well as to identify any errors or deficiencies that remained in the product. The self-evaluation identified weaknesses in content, presentation, language, and graphical aspects of Prototype I. These findings served as the basis for revising Prototype I, resulting in Prototype II.

The instruments used in this study consisted of an interview guide, a student needs analysis questionnaire, and a self-evaluation checklist. The interview guide was developed to identify learning conditions, the use of teaching materials, and teachers' needs for student worksheet development. The student needs analysis questionnaire was developed to identify students' learning needs and preferences regarding acid-base learning and the development of student worksheets. The self-evaluation checklist was developed based on the quality criteria of student worksheets, including content, presentation, language, and graphical aspects, to evaluate Prototype I before revision. The development of these instruments was guided by the objectives of the preliminary research and relevant literature on instructional material development to ensure that the collected data were aligned with the purpose of the study.

Prior to data collection, all instruments were reviewed to ensure their clarity, relevance, and alignment with the objectives of the study before being used in the preliminary research. Because the instruments were intended to obtain preliminary information for product development rather than to measure latent constructs, formal reliability testing was not conducted. Instead, consistency was maintained through structured interview guidelines, standardized questionnaires, and a self-evaluation checklist.

Research data were collected through interviews, questionnaires, literature review, and self-evaluation. Interviews and questionnaires were conducted during the preliminary research to obtain information on learning conditions, the use of teaching materials, and the needs of teachers and students regarding the development of student worksheets. A literature review was conducted to establish the theoretical foundation for product development. Furthermore, Prototype I was evaluated through a self-evaluation checklist, and the findings served as the basis for revising the product into Prototype II.

Interview data were analyzed using qualitative descriptive analysis through the stages of data reduction, data display, and conclusion drawing. During the data reduction stage, information relevant to learning conditions, the use of teaching materials, and the need for student worksheet development was selected. The reduced data were then categorized into key themes and presented descriptively before conclusions were drawn.

Questionnaire data were analyzed descriptively by calculating the percentage of each response. The percentage of each response was calculated to describe students' learning needs and preferences regarding acid-base learning and the development of student worksheets.

Self-evaluation results were analyzed descriptively based on the indicators in the checklist, including content, presentation, language, and graphical aspects. The identified weaknesses in Prototype I were used as the basis for revising the product, resulting in Prototype II.

RESULTS AND DISCUSSION

This study used the Plomp development model and was limited to the preliminary research and prototyping phases, resulting in Prototype II through the self-evaluation stage. The research results are presented based on the Plomp development stages, which include preliminary research and the prototyping phase.

Needs and Context Analysis

The needs and context analysis stage aimed to identify the needs of teachers and students and examine the learning resources used in acid-base learning. Data were collected through interviews with four chemistry teachers, questionnaires administered to 60 Phase F students at SMAN 2 Pariaman, SMAN 4 Pariaman, and SMAN 2 Sungai Limau, and an analysis of the teaching materials and student worksheets used in schools. The findings from this stage served as the basis for designing the Guided Discovery Learning-based acid-base student worksheet integrated with ethnoscience.

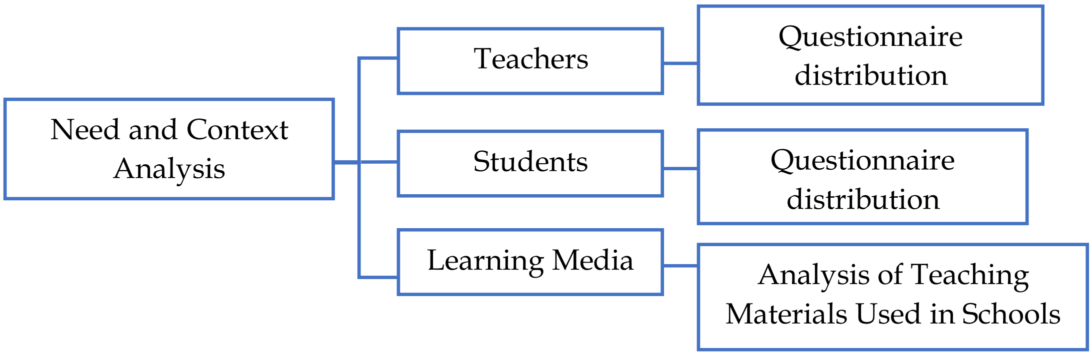


Figure 3. Needs and Context Analysis

Interview results also indicated that the learning process has been moving toward the implementation of the Independent Curriculum. However, in certain situations, teacher explanations still dominate learning because students struggle to analyze concepts and learn independently. This situation indicates that students' opportunities to construct knowledge independently are still limited, thus the development of critical thinking skills cannot be optimally facilitated. This finding is in line with Salame et al., (2022) which states that learning that is still centered on the teacher tends to provide less opportunity for students to develop critical thinking skills through the process of investigation and discovery of concepts.

Analysis of teaching materials shows that the learning resources used are still dominated by textbooks, teaching modules, PowerPoint presentations, learning videos, and conventional student worksheets prepared by teachers. Based on interviews, these teaching materials generally contain material descriptions, example questions, and exercises, thus not being able to facilitate students' independent discovery of concepts. Furthermore, all teachers stated that they had never implemented the Guided Discovery Learning model in acid-base learning, so learning activities designed to train students' critical thinking skills have not been optimally implemented. These findings align with research showing that teaching materials that are still oriented towards delivering material are not able to encourage students to build concepts through an active discovery process (Rahmawati et al., 2023).

The results of the student questionnaire showed that 98.3% of students had never used a student worksheet based on Guided Discovery Learning integrated with ethnoscience in chemistry learning. This finding indicates that students have not yet gained learning experiences that integrate concept discovery activities with local cultural contexts as part of the chemistry learning process.

Literature Review

The literature review provided the theoretical foundation for determining the components and characteristics of the developed student worksheet. It covered the acid-base topic, Guided Discovery Learning, ethnoscience, Ennis' critical thinking indicators, and previous studies relevant to student worksheet development. Previous studies have shown that the acid-base topic remains one of the chemistry topics that presents difficulties in conceptual understanding because it involves relationships among observable phenomena, submicroscopic processes, and symbolic representations (Salame et al., 2022). Based on these findings, the student worksheet was designed according to the Guided Discovery Learning syntax to facilitate students in discovering concepts through systematic learning activities while fostering critical thinking skills (Yerimadesi et al., 2023).

In addition, the ethnoscience approach was integrated by connecting acid-base concepts with local cultural phenomena, making learning more contextual and meaningful (Izah et al., 2020). The use of cultural contexts in ethnoscience-based learning enables students to relate their prior knowledge and experiences from their surrounding environment to scientific concepts learned at school, thereby supporting a more relevant knowledge construction process (Atmojo et al., 2025). However, the integration of ethnoscience should not only involve presenting cultural practices as learning examples but also requires a scientific reconstruction process to transform local knowledge into scientific concepts that are consistent with established scientific principles (Anugrah et al., 2025; Selamat & Priyanka, 2023). This process helps ensure that cultural phenomena are explained using appropriate scientific concepts, thereby reducing the potential for students' misconceptions (Anugrah et al., 2025). Furthermore, Ennis' critical thinking indicators were used as a reference for developing SW activities and guiding questions to facilitate students' critical thinking through clarification, basic support, inference, advanced clarification, and strategy and tactics (Ennis, 2011).

Conceptual Framework

The conceptual framework is prepared based on the results of needs analysis, context analysis, and literature studies.

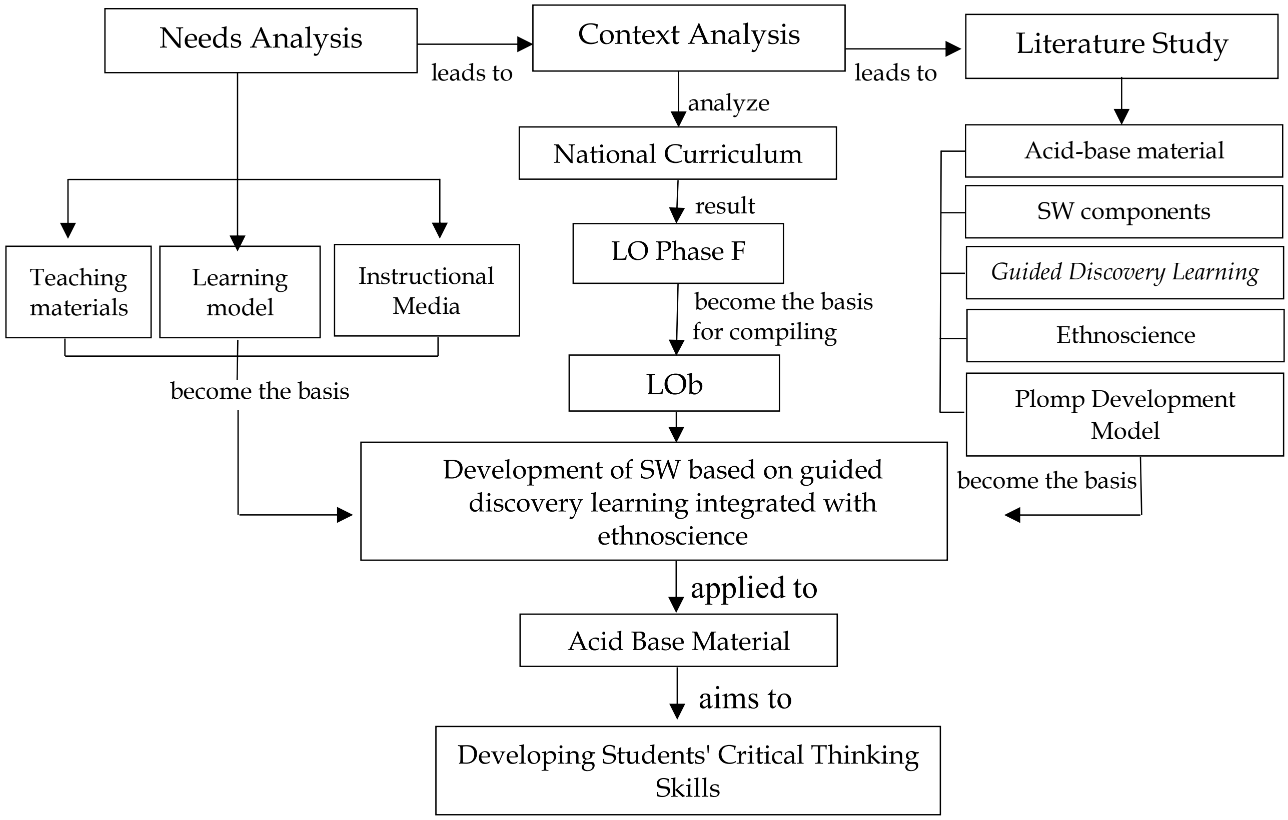


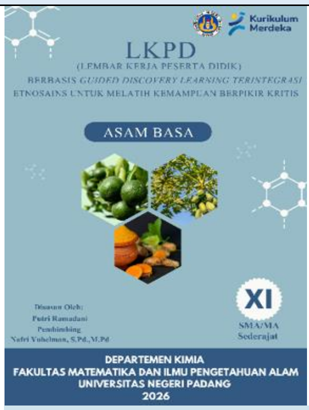
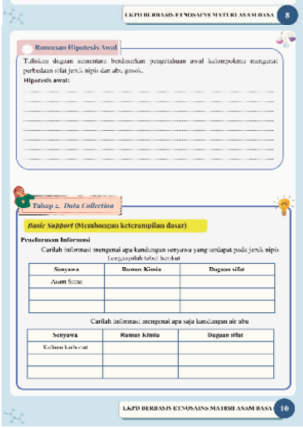
Figure 4. Conceptual Framework

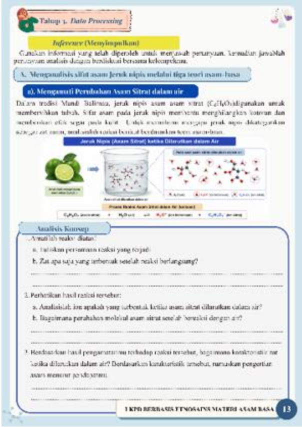
Initial Plan

Prototype I was designed as the initial version of the student worksheet based on the findings of the needs analysis, context analysis, literature review, and conceptual framework developed during the preliminary research phase. The student worksheet was developed by integrating Minangkabau ethnoscience into the acid-base topic and incorporating the Guided Discovery Learning syntax, consisting of Motivation and Problem Presentation, Data Collection, Data Processing, Verification, and Generalisation.

The results of Prototype I are in the form of Acid-Base Student Worksheets Based on Guided Discovery Learning Integrated with Ethnoscience to Train Thinking Skills in Phase F of Senior High School/Vocational High School. The developed Student Worksheets consist of: (1) cover, (2) foreword, (3) table of contents, (4) instructions for use, (5) learning outcomes, (6) learning objectives, (7) concept maps, (8) learning activities based on Guided Discovery Learning integrated with ethnoscience, (9) evaluation, (10) bibliography, and (11) compiler profile. (Kementerian Pendidikan Nasional, 2010).

Table 1. Creating SW Based on GDL integrated with ethnoscience and critical thinking indicators

Page	Design	Expalanation
Cover View		According to Prastowo (2012), good teaching materials need to pay attention to the visual aspect (graphics) to attract students' interest and facilitate their use. Based on this principle, the SW cover is designed to include the title, illustrations representing the acid-base material, and the identity of the compiler.
Curriculum Page		The curriculum page is compiled based on Learning Outcomes (LO) determined by the Education Standards, Curriculum, and Assessment Agency (BSKAP, 2025). This page contains , Learning Objectives (LOb), and acid-base material as a reference in compiling learning activities in SW.
Motivation and Problem Presentation		The Motivation and Problem Presentation stage is designed according to Guided Discovery Learning syntax, presenting ethnoscience phenomena that link acid-base concepts to everyday life, thus motivating students and helping them identify problems. This stage trains elementary clarification skills as an indicator of critical thinking.
Data Collection		The Data Collection stage is designed through ethnoscience-based data collection to obtain information that supports understanding of acid-base material. This stage trains basic support skills.

Data Processing		The Data Processing stage is designed through activities to process and analyze the data obtained and relate it to ethnoscience to build an understanding of acid-base material. This stage trains inference skills as an indicator of critical thinking.
Verification		The Verification stage is designed to verify the results of data analysis by linking them to ethnoscience phenomena to prove the answer to the problem. This stage trains advanced clarification skills.
Generalization		The Generalization stage is designed through activities to draw conclusions based on analysis results linked to ethnoscience phenomena to strengthen understanding of acid-base material. This stage trains inference skills as an indicator of critical thinking.

Self Evaluation

From the conceptual design that has been developed, the researcher carries out the execution for product creation until it produces a product in the form of prototype I. This product is then reviewed by the researcher himself to catch obvious errors through a self-evaluation questionnaire (Hidayat et al., 2022). Revisions made based on the results of this review resulted in prototype II. The aspects used as references in this self-evaluation are presented in Table 2.

Tabel 2. Self Evaluation

Aspect	Deficiencies		Remarks
	Present	Not Present	
Cover		✓	The cover is in accordance with the of the SW
Curriculum Alignment		✓	It is aligned with the Phase F Learning Outcomes (LO) and Learning Objectives (LOb)
Content		✓	The content is aligned with the learning objectives
Guided Discovery Learning Syntax		✓	The Guided Discovery Learning syntax has been implemented completely

Aspect	Deficiencies		Remarks
	Present	Not Present	
Ethnoscience Integration		✓	Ethnoscience integration has been incorporated into the learning activities
Critical Thinking Skills (Ennis)		✓	Ennis' critical thinking indicators have been incorporated into each GD Learning syntax.
Language	✓		There are several typos in the writing of words
Presentation		✓	The presentation is systematically organized
Graphics	✓		Some images are still unclear

Prototype II was produced after a self-evaluation of Prototype I using a checklist to identify product deficiencies before validation by experts (Tessmer, 1993). The self-evaluation was conducted on several aspects, including cover design, curriculum suitability, materials, *Guided Discovery Learning* syntax, ethnoscience integration, Ennis's critical thinking indicators, language, presentation, and graphics. The evaluation results showed that most components of the student worksheet met the established criteria; however, several improvements were identified in the language and graphics aspects. Revisions were made by correcting typographical errors and improving the clarity of several images to enhance the readability and presentation quality of the student worksheet .

The development of Prototype II also considered the alignment between the Guided Discovery Learning syntax and Ennis's critical thinking indicators as a design framework for organizing learning activities in the student worksheet. This alignment is consistent with the constructivist perspective, which emphasizes that knowledge is actively constructed through learners' engagement in meaningful learning experiences. In addition, the integration of ethnoscience provides culturally familiar contexts that serve as the starting point for concept exploration, allowing students to reconstruct local knowledge into scientific understanding through the Guided Discovery Learning process. The integration of Ennis's indicators was intended to ensure that each GDL stage contained activities designed to facilitate specific critical thinking processes. The Motivation and Problem Presentation stage was designed to facilitate Elementary Clarification by encouraging students to identify problems from ethnoscience-based phenomena. The Data Collection stage was associated with Basic Support by guiding students to gather relevant information and evidence. The Data Processing stage was designed to support Inference by encouraging students to analyze the collected data and formulate preliminary conclusions based on the available evidence. The Verification stage was related to Advanced Clarification by encouraging students to evaluate and justify their findings using scientific concepts. Finally, the Generalization/Closure stage was linked to Inference by guiding students to draw final conclusions and formulate general principles based on the results of the learning process. Therefore, the integration of Guided Discovery Learning syntax, ethnoscience contexts, and Ennis's critical thinking indicators provides a coherent conceptual framework for designing learning activities oriented toward facilitating critical thinking processes. However, the effectiveness of the developed student worksheet in improving students' critical thinking skills requires further validation, practicality testing, and effectiveness testing.

CONCLUSION

This study produced Prototype II of an acid-base student worksheet based on Guided Discovery Learning integrated with ethnoscience as an initial learning design for Phase F students. Prototype II was developed through the self-evaluation of Prototype I by improving the content, presentation, language, and graphical aspects. The developed student worksheet integrates Guided Discovery Learning syntax, Minangkabau ethnoscience contexts, and Ennis' critical thinking indicators as the basis for designing systematic learning activities. The resulting Prototype II represents the outcome of the preliminary development phase and is ready for expert validation as the next stage of the development process. However, because this study was limited to the preliminary development stage, further studies involving practicality and effectiveness testing are needed before the developed student worksheet can be implemented more broadly in chemistry learning.

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